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ORIGINAL ARTICLES.

I.—Notes on Russian Geology.

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PLATES X. and XI.

Cretaceous.

In the summer of 1891 a journey was undertaken by the writer to the S.W. Governments of Russia, the immediate object in view being the study of the geology of that region. This portion of the notes then taken will deal more especially with the extent, thickness, and general contour of the Cretaceous beds of the district, together with a review of the Russian literature bearing on the zonal distribution in the various Governments.

In 1845 Murchison had gathered together most of the facts then known regarding the Cretaceous formation of S. Russia, but his own direct observations were few, and the work was considered of only secondary importance. Under these circumstances it would not have been very surprising to find that he had fallen into error on many points.

In discussing the Chalk of the Donetz Basin, Murchison had already pointed out the great resemblance of the Russian beds to their W. European representatives, both in their faunal and lithological characteristics, and subsequent research has shown that it is possible to arrange the strata into divisions corresponding to those adopted by French authors.

The main discussion will be restricted to the governments of Kieff, Poltava, Tchernigov, Kursk, and Kharkoff; these districts being those which came most under my immediate notice. In addition to numerous personal visits to the finest exposures, I had the further advantage of being supplied by Messrs. Winning Brothers, of Kharkoff, with detailed copies and a few samples of the principal bores worked by them during the last few years. Amongst these the bore at Kharkoff reveals the greatest thickness of Chalk yet known in Europe (Plate X. Fig. 1). Taking this city as a centre, a section, running from Gluskhovo through Soumy and Achtirka to Kharkoff, and thence to Borki may be constructed from the data to hand.

To illustrate Mr. Hume's paper on Russian Geology.

The heights of the principal localities may be easily correlated with the level of the Chalk beneath the surface:—

	Height, feet.		
Gluskhovo	511	...	Chalk 78 ft. below surface.
Soumy ...	488·3	...	Chalk 147–199 ft. below surface.
Achtyrka	402·08	...	Not reached at 454 ft. (Phosphorite layer only reached).
Kharkoff	354·2	...	Chalk reached at 132·9 ft.
Borki ...	636·51	...	Not reached at 529 ft. (Phosphorite layer).

(See Plate XI. Fig. 2).

It will be evident by mere inspection that the following general points may be observed in Fig. 1 and 2: first, that the Tertiary beds are divisible into two main divisions (1) an Upper, more sandy division; (2) a Lower, more clayey division; second, that the Chalk strata are divisible into three main lithological divisions (1) a pure white Chalk, in the main soft; (2) a more marly Chalk; (3) a firm, hard Chalk. Finally there is at the base a greensand, as in England, followed by a few grey clays and sands.

Secondly, it will be seen that the thickness of the Chalk strata at Kharkoff alone almost doubles that in the London and Paris Basins.

A closer analysis of the Kharkoff bore yields the following details of structure (the 133 feet of Tertiary beds are not at present discussed):

	Feet	in.
White soft Chalk	297	0
Ditto (more bluish)	221	0
Ditto (less blue)	449	0
Ditto (somewhat clayey) ...	134	0
Bluish Chalk Marl	101	0
Ditto (darker and lighter) ...	156	0
Grey firm Chalk	137	0
Ditto (more white and soft)	148	0
Ditto (with fossils) ... ... Fragments of a Belemnite and Inoceramus.	7	0
Ditto (with green clayey bed)	10	0

	Feet	in.
Grey firm Chalk (more clayey)	7	3
White Chalk	100	0
Ditto soft	61	0
Ditto hard (with glauconite)	3	0
Green sandy clay	20	0
Grey sand	4	3
Hard bound grey sand	1	9

After these follow green and grey sands, alternating with dark sandy clays. At a depth of 2107 ft. 8 in. below the surface fossil wood was met with in a coarse grey sand.

In the Soumy bore there is less detail (Tertiary beds here 200 feet thick).

Very soft white Chalk	216 feet 6 inches. 3 ft. 6 in. firm bed between.
Ditto (light bluish)	143 feet.

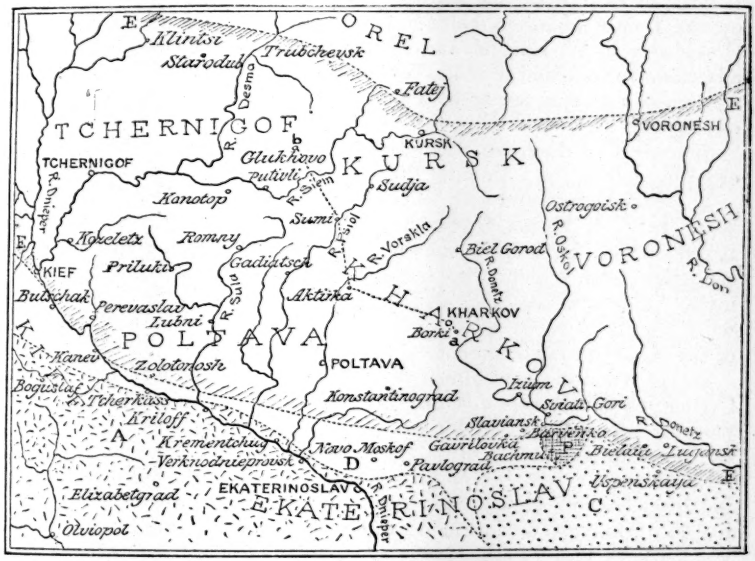
Then follow a series of alternations of hard and soft Chalk beds, to a depth of 954 feet. At 898 feet there is a very hard bed with bluish sandy balls, and at a depth of about 900 feet dark flints make their appearance in a hard Chalk bed. Below this hard bed (50 feet thick) commences the Chalk Marl, the latter being over 150 feet thick when the boring ceased. In the Glushkovo bore (excluding 78 feet of Tertiary and later beds) 105 feet of clean soft white Chalk were passed through before the boring was finished.

Although the want of fossils is marked, and the outcrops are few and far between, it may yet be possible to obtain a few details as to the faunal characters of the beds. For this purpose I undertook a journey to Bielgorod, 75 versts to the N. of Kharkoff, visiting as many quarries as it was possible during the time at my disposal.

The beds evidently correspond to the highest series in the above tables, as they are soft white Chalk, and immediately underlie the Green Tertiary Sandstones. These beds yielded a most abundant crop of *Belemnitella mucronata*, but beyond these, and a fragment of a thin-shelled *Inoceramus*, no other forms were obtained.

Prof. Armachevsky, who has been engaged in the task of mapping the northern portion of the area now under discussion, has examined the exposures of Chalk and Chalk Marl displayed in the courses of the Rivers Siem and Psiol. (A large number of localities are given by him which I need not mention here). The strata consist in the main of a white, massively-jointed Chalk, Chalk Marl only cropping out in the N.E. corner, towards Kursk. The following fossils occur in the first-named: *Cidaris vesiculosa, Echinocorys ovata, Terebratula carnea, Ostrea vesicularis,* and *Pecten splendens.*

MAP OF SOUTH RUSSIA (CENTRAL PORTION) REFERRED TO IN PAPER.



A	C	P	D	E
Archæan (Gneisses and Granites).	*Carboniferous (Shales, Sandstones and Limestones).*	*Permian.*	*Doubtful (in this area Cretaceous, Jurassic, and Carboniferous have been met with).*	*Approximate Boundary of Upper Cretaceous.*

The Tertiary Beds covering a large part of the country are treated as though they had been denuded away.

a to b indicates Line of Section on Map.

In the Tchernigov Government to the N.W. a large series of fossils have been met with, but they seem to show that the zonal arrangement holds far less for this E. end of the European

Cretaceous basin. At the same time most of the genera are the same as those occurring in the English Chalk, and the results may be analysed as follows:

		In Western Europe.
Common or mixed forms	*Ostrea vesicularis* ...	Whole Upper Cretaceous.
	,, *flabelliformis* ...	Turonian and Senonian.
	Spondylus spinosus ...	Ditto ditto.
	Parasmilia centralis ...	Ditto ditto.
Senonian forms ...	*Echinocorys ovata* ...	*Belemnitella mucronata* Zone.
	Terebratula carnea ...	Do. and Micr. cor-anguinum Zone.
	Magas pumilus ...	*Belemnitella mucronata* Zone.
	Belemnitella mucronata	Ditto.
	Pecten undulatus ...	Marsupites Zone.
	Many Ventriculites.	
And probably most of the Fish remains		*Beryx*, *Corax*, *Ischyodon*, etc.
Cenomanian forms ...	*Cidaris vesiculosa* ...	*Pecten asper* and Chloritic Marl.
	Serpula gordialis ...	*Pecten asper*.

It will be seen from the above list that by far the greater number of the fossils obtained belong to the higher beds of the Upper Cretaceous in W. Europe, and it is therefore, on the whole, perhaps advisable to conclude that the White Chalk and Chalk Marl represent a Senonio-Turonian series in which divisions are not sharply marked off as with us.

Summing up then, we may conclude that the Cretaceous beds are cropping out in the following order from S. to N.:

1. Chalk (white and soft, in N. Kharkoff Government). 2. Chalk Marl (in S. of Kursk Government). 3. The phosphoritic grits of Kursk, which have been shown to be Cenomanian by the Russian geologists, and which crop out some five versts N. of the above town. A few words may also be of interest as to the work done with regard to these beds in the Governments on the N.E. and E. of the Kharkoff Government.

In the Saratov Government Prof. Sintzoff has noticed two upper Cretaceous divisions—a sandy and a marly or chalky division; passing into one another by gradual lithological change; he divides the latter again into (1) Chalk; (2) Chalk Marl; (3) Sponge beds, with numerous remains of sponges. (This has not been met with in the Kharkoff bore.) The same Professor has again remarked for the Simbirsk Government that there are two main divisions, viz.: Chalk and Chalk Marl, inseparable from one another, both on palæontological and stratigraphical grounds. Below this occurs glauconitic chalk, with phosphatic nodules. In the above views Professor Lagusen concurs. Professor Sintzoff has also come to the conclusion that the fauna of these beds is a mixture of Senonian and Turonian forms. Professor Lagusen has remarked that the fauna of Simbirsk is mainly Senonian, but at the same time Turonian forms occur, and this condition holds for other Governments, wherever studied (Voronesh, Don Cossack country, Kursk, Kharkoff, and Ekaterinoslav).

Prof. Borusak also has divided these beds into White chalk, Chalk Marl, and Glauconitic marly sandstones. For the Kursk Government Hofmann has shown that the famous phosphorite grit or

Northern Bone Bed of Kiprianov contains numerous sponges (*Porospongia, Cribrospongia concentrica*), and has referred these to the Cenomanian.

In the Chalk Marl he found *Ostrea carinata, O. canaliculata*, etc., and referred it to the *Turonian*, and finally the soft chalk with flints and *Belem. mucronata, O. vesicularis*, and *O. semiplana* he considered Senonian. (These results must, however, be modified as shown above.)

2nd. The development of the Cretaceous Basin to the west of the central area may next be considered. Data from borings are very scarce, the only boring of any importance being the Letunofsky one, at Gorbunovka, near Poltava. The Tertiary and more recent beds here attain a thickness of over 670 feet, after which 231 feet of soft, white chalk was passed through. The bore was then discontinued, it being concluded that the Chalk might prove to be thicker than the deposit at Kharkoff.

While a good deal of work has been lately done with regard to the Tertiary deposits of the Poltava Government, no mention has been made of any exposures of the Cretaceous system in that part of the country.

We must go to the neighbourhood of the town of Kieff for conclusive evidence as to the presence of Cretaceous beds on the west of the Poltava Government. I am informed that a bore in the lower part of the town of Kieff passed through 30 feet of chalk, but have been unable to obtain the paper in which Prof. Theophilaktoff discusses this occurrence. This bed probably soon thins out and dies away at the great Archæan axis.

Further to the south (see map) along the course of the Dnieper, between Tripolie and Tcherkass, occur a series of beds of a glauconitic sandy nature, containing fossils of Cenomanian age, such as *Amm. Mantelli, Amm. varians, Exogyra conica*, and *Janira quinquecostata*. These beds are 80 feet thick, and have undergone considerable step faulting. The main dip is 30° S.W. that is, away from the river. [It would be of interest to know whether there is much trace of faulting along the course of the Dnieper, such as occurs along the Thames valley. Certainly the very high escarpment on the right side of the river, which forms such a picturesque object at the town of Kieff itself, might be due in some measure to such earth movements, just as there is a similar escarpment in the central portion of the course of the Donetz, and also on the Volga, the right bank being always the higher side.] The Cretaceous sands above-mentioned are surmounted by the Tertiary sandstones of Butschak and Traktemirov, whose fauna was already well known in Murchison's time. A little further down the river, at Krementchug, I observed gneisses well marked on the east side of the river, so that the Cretaceous deposits probably do not extend far south of their known outcrop as mentioned above. These beds rest upon Jurassic strata, with which they appear to be comformable.

3rd. In a direction S.E. from Kharkoff the Cretaceous beds have an enormous extension. Hidden under the Tertiary beds for

a time, the Chalk reaches the surface in the neighbourhood of Izium. Here, as shown by Murchison, the Chalk is 30 feet thick; underneath these are greensand beds 70 feet thick, and then come 44 feet of Upper Jurassic beds. As this spot is 70 miles S.E. of Kharkoff, and no other Jurassic outcrop occurs between the two towns, it is probable that the Chalk slowly thickens towards the North.

Further to the S. a splendid display of the Upper Cretaceous and its subjacent beds occurs at the great monastery of Sviati Gori, in the fine escarpment overlooking the Donetz. The upper 300 feet consists of a somewhat coarse chalk, containing layers of flints. Below it occurs a large mass of somewhat fine greensand, which yielded no fossils to our research. It is well displayed in the winding road down to the river. I was unable to obtain sufficient evidence as to its exact thickness. It was certainly at least 15 to 20 feet. As will be seen, this greensand occupies an enormous area, and very probably belongs to the Pecten asper zone (Murchison).[1]

Variegated clays separate the greensands from the Jurassic limestones which form a second low cliff near the river. These beds are practically unfossiliferous, although strata of similar lithological character at Shilovka, near Simbirsk, yielded *Amm. consobrinus* to the researches of M. Jasikoff (see Murchison), and they may perhaps like them be referred to "couches supérieures Neocomiennes" of D'Orbigny.

Thus a comparison gives:

Kharkoff.	Izium.[2]	Sviati Gori.
Tertiary, 133 ft.		
Chalk and Chalk Marl. (1831 ft.)	Chalk. (30 ft.)	Whitish Chalk (about 300 ft.)
Green and grey sands.	Greensand (70 ft.)	Greensand (? more than 20 ft.)
Same alternating with dark clays.	.....	Variegated clays.
	Jurassic Limestones.	Jurassic Limestones.

From Sviati Gori the Chalk area extends unbroken 20 miles to the south at Kramatorovka. The whole of the country between these two points consists of undulating steppe, the understratum of chalk being barely concealed by a thin covering of grass, whilst

[1] It may be noted that the repetition of the Jurassic Strata at Sviati Gori, at Kamenka, and at Tzium, is regarded by Prof. Gourov as being due to a succession of faults. It again raises the question how far parts of the courses of important rivers have been determined by such movements of the earth's crust. Prof. Gourov has shown the existence of Jurassic limestones not far from Poltava, so that it is probable that Upper Cretaceous beds do not extend far to the S. of that town.

[2] At Fedorovka, in the Izium district, a boring by Messrs. Winning, has shown the existence of 451 feet of variegated, green, and red clays, which probably belong to the same category as those mentioned above. At a bore between Barvenko and Stavrikov, in the valley between the stations of Gavrilovka and Slaviansk, the beds vary remarkably in their lithological character. For the first 50 feet variegated and brown clays predominate; the next 150 feet are sands and sandstones. For the next 100 feet there is contest between the clays, sandstones and limestones, the latter forming two or three bands 6 ft. thick, separated by wide intervals. The remaining 228 feet are almost entirely variegated brown clays. It is possible that these beds were deposited near a shore line, the sea, in which the Oolitic limestone of Sviati Gori was laid down, occasionally reinvading the district. Subsequently the clays themselves invaded the Jurassic sea, and covered the limestones, as at Sviati Gori.

in every gully the chalk is seen to form the walls. In one of these the inevitable *Belemnitella mucronata* came to light.

It would seem as though the Cretaceous beds were sweeping round the Jurassic which bordered them on the W. side, and underlie them at Izium, Kamenka, and Sviati Gori. They then skirt the edge of the Permian district which contains the splendid Briansсoe and Stupki salt mines. Two points of interest here attracted attention, viz. that the alabaster hills stretching N. from Bachmut to Stupki were covered with flints, and that the Chalk forms a sharply marked escarpment stretching all along the left side of the railway from Kramatorovka to Vierolubovka. The conclusion seems irresistible, viz. that Chalk beds extended much farther to the S. over the Permian area, the flints being evidence of the past denudation and the escarpment evidence of that now proceeding.

Further to the E. the Upper Cretaceous actually overlaps the Carboniferous, and several coal-mines have been sunk through the Chalk to the Carboniferous deposits below. As Murchison had long ago remarked, the Chalk appears to occur in basins or pockets, filling up spaces between highly inclined Carboniferous strata. Thus he pointed out that an artesian well at Lugansk was made, 630 feet deep, Chalk being passed through all the time. At Uspensk again, white chalk occurs, containing *Inoc. Cuvieri, Lima semisulcata, Ostrea vesicularis*, and *Belemnitella mucronata*, and possessing bands of flints. The dip is N.N.E. He also mentions small tracts of Greensand to the N. of Lugansk, rising from beneath the Chalk, and loaded with *Exogyræ* and *Ostrea vesicularis*.

A remarkable case is presented by a boring recently carried out near Bielaia, close to the junction of the Cretaceous and the Carboniferous. About two-thirds of a mile from the station coal is being worked in true Carboniferous strata; at the station a bore has been constructed which passes through 600 feet of Chalk Marl, and below this through 200 feet of soft white chalk. At this point the bore was stopped, and no definite opinion as to the junction of the Cretaceous and Carboniferous can be stated.

Passing in the direction of Lugansk, to the E., some little distance along the railway, I noticed a very deep and well marked ravine. Not far removed from this ravine was an exposure of greensand. It appeared as though the great depth of Chalk at Bielaia might be due to faulting, the direction of the fault-plane being coincident with the ravine above-mentioned.

To the E. the Cretaceous passes under Tertiary beds, and not having been further in that direction, we must call attention to the work by Prof. Golovkinski, on the geology of the Taurida Government, as revealed by artesian borings.

Some 70 m. to the N. of Melitopol, on the Azoff Sea, a bore has been constructed at Oriechov, which shows the existence of the Cretaceous directly overlying the Archæan at that point. At Voskresenka, to the E. of this place, the Cretaceous ceases, and the remains of the Archæan axis separates it from the shores of the Sea of Azoff. This axis is not, however, complete to the N.W. a large

strait of Miocene beds occupying the intervening space. The borings have shown that starting from a point 80 miles N. of Melitopol, the Tertiary beds attain their maximum thickness under the Azoff Sea, really forming an immense synclinal basin, bordered at one extreme by the Cretaceous and Archæan of the Don Cossack country, and on the other by the Cretaceous, the Jurassic, and Archæan of the Southern Crimea.

From the above data it will now be possible to form some more precise idea of the extent of the Central and South Russian Cretaceous Basin, and to trace its boundaries more sharply than has hitherto been possible. With that view I have visited many crucial points, and have made a study of various Russian writings either in the original or from references in other pamphlets.

(A map should be referred to in following out these conclusions:)

1. One boundary of the Cretaceous basin is very closely connected with the course of the Dnieper, the Chalk thinning out near Kieff, as shown by boring, the Cenomanian and Albien (as shown by Theophilaktoff) resting directly on Upper Jurassic W. of the Dnieper, therefore Cretaceous deposits cannot be of great extent, and must die away against the Archæan axis.

2. The Jurassic beds follow the line of the Archæan axis towards the S.E., the Cretaceous beds being thus limited to the N. The outcrop of these beds therefore bends sharply to the E. passing S. of Poltava, and resting directly (both Cenomanian and Senonio-Turonian) on the Upper Jurassic beds at Izium, Kamenka, and Sviati-Gori (Gourov and personal obs.) Borings also lead to the conclusion that the Jurassic beds are developed in the N. of the Ekaterinoslav Government to an extent not previously imagined.

3. The boundary then successively rests on Permian (near Bachmut) and on Carboniferous parallel to the S. bank of the River Donetz before it takes a bend to the E. From this point the Cretaceous expands in the Don Cossack country, sending off an arm, which, passing under the Tertiaries of Taurida, reappears in the Cretaceous hills of S. Crimea (Golovkinski). The main mass passes southward towards the Caucasus, disappearing under the Aralo-Caspian strata that occupy the space between the Azoff and Caspian Seas. Their boundary is probably somewhat N. of the main Caucasus range, as Neocomian fossils have been met with both at Kislovodsk and Piatigorsk.

It would be scarcely right to include in this paper the deposits containing *Inoc. Cripsii* and *Belem. mucronata,* which occur in the S. Caucasus and in Armenia and Daghestan, especially as these present the characters of the Southern Cretaceous type. With this limitation, the extension of the beds to the W. may be next studied, and in the provinces of Voronesh, Simbirsk, and Saratov, as also in the Obschei Sirt Hills, white chalk (apparently closely related to the Senonio-Turonian already mentioned) is developed on an immense scale. Murchison has shown that near Indovistye, W. of Voronesh, the W. chalk is only 20 feet thick and immediately overlaps the Devonian, 100 feet of Greensand (Cenomanian) occurring below.

150 m. to the E. at Volsk on the Volga the chalk is 200 feet thick containing *Belemnites?* possibly *Belemnitella, Pecten* (like *quinquecostata*). There is, however, a more general tendency for the Cretaceous beds to become clayey or sandy in the two Governments of Simbirsk and Saratov. The former condition prevails in the Simbirsk, the latter in the Saratov Government. Thus, at the town of Saratoff itself, Murchison had previously shown that the Upper Cretaceous beds, include white, grey, and bluish marls containing *Belemnitella mucronata* and *Pecten cretosus.* In the N. of the Simbirsk Government Neocomian and Aptien beds occur, and only the S. portion of the Government is occupied by the Upper Cretaceous. Finally, Sintzoff has shown that the Cretaceous is represented by soft Chalk and Chalk Marls in the Obschei Sirt, a band of hills in the neighbourhood of Orenburg. The white Chalk at Uralsk here contains *Belem. mucronata,* and *Echinocorys ovata,* thus probably forming the E. part of the great central basin. On the Siberian side of the R. Oural these beds sink beneath the Tertiary of the Kirghese steppes. It will be advisable to give the succession in a few typical localities in these Western Governments, so that a clear idea may be formed of their general characteristics.

The succession near Simbirsk (Yasikoff) is as follows (see Murchison).

I. (1) White Chalk, with courses of chert, occasional deposits of tripoli, and masses of ferruginous ochre. (2) Chalk Marl with bands of chloritic Chalk, in lower parts of which occur *Inoc. Cuvieri, Bel. mucronata,* and Zoophytes. (3) Marls with phosphatic nodules. Total above 250 feet.

In the Upper beds occur *Tereb. carnea, T. subrotunda, Micraster coranguinum, Plagiostoma Hoperi, Bel. mucronata, Scaphites æqualis,* with Zoophytes, Crustaceæ, and teeth and vertebræ of fishes.

II. Below these occur 300 feet of variegated clays, containing *Amm consobrinus* (Upper Neocomian). Their position reminds us of similar clays below Greensand at Sviati Gori.

III. The base is formed by the Besonov and Simbirsk clays, containing such typical forms as *Inoc. concentricus,* and *Hoplites Deshayesii.*

Lower down the Volga, at Kwalynsk, Chalk 200 feet thick occurs, resting directly on Jurassic sands and shales.

The characters of the strata at Volsk have been mentioned on the previous page.

Still following the Volga, we arrive at the town of Saratov, with the beds well exposed on its shores. There is here a lithological difference, and in Fig. 344 (Murchison's "Russia and the Urals") the succession is given as follows:—1. Grey clays with *Ostrea vesicularis.* 2. White, grey, and bluish marls with *Bel. mucronata* and *Pecten cretosus.* 3. Sponge-bearing strata. 4. Calcareous sandstones, with *Terebratula* and *Ostrea lateralis.* Below these come Jurassic beds.

100 miles to the S. at Kamischine, Inostranzoff mentions Neocomian and Aptien zones, whilst further S. at Bielaiaglina (white clays) pure white Chalk occurs containing *Terebratula carnea.*

We have thus followed Murchison in taking a typical series of localities on the Volga, the evidence showing that the Cretaceous, especially the Upper White Chalk, is strongly developed over a wide superficial area, though never apparently attaining any considerable thickness.

IV. Leaving the Volga district to the E. the boundary of the Senonio-Turonian basin passes to the N. of the Voronesh Government, to the N. of the Kursk Government and also through the N. of the Tchernigov Government, resting at Klintsi, on glauconitic ferruginous sands, sandstones and limestones, containing fossils of Cenomanian age. We have thus traced the great central basin (presumably Senonio-Turonian) from all evidence now to hand, showing its junction with the Cenomanian at points widely distant from one another, and the question now arises, How far can this basin be traced to the westward? At this point we must take advantage of the great Russian text-book, written by Professor Inostranseff, and the evidence he adduces proves that this basin is to be met with almost up to the Russo-German Frontier.

In Podolia and Volhynia white Chalk, Chalk Marl, and marly sands, are all met with.

In the main governments of Poland the same condition of things occurs, but here the Chalk Marl is rich in Turonian fossils, and there would appear to be more sharply defined limits between the Turonian and Senonian as we pass westward. In the Lublin Government (S. Poland) these beds are well developed, being 300 to 540 feet thick, and resting directly on glauconitic sands or marls containing Gault fossils.

The Upper Cretaceous has also a wide extension in the N. of the Government of Grodno, as also in Kovno and Courland, and there seems no reason to doubt that the great Russian Upper Cretaceous area is thus directly united with the Swedish deposit, and is only hidden by a thick series of Tertiary beds.

Conclusions as to Central and Russian Upper Cretaceous Basin (Exclusive of Cenomanian).

1. Its length from E. to W. is almost equal to the greatest breadth of the Russian Empire (over 1200 miles). This is reckoned from the River Vistula, near Lublin, to the River Oural, near Orenbourg.

2. Its general breadth may be taken at 200 miles from N. to S. Thus from Kursk to Tzium this breadth is attained.

3. Its greatest known depth is attained at the town of Kharkoff (1831 feet), thus presenting the greatest thickness of Chalk and Chalk Marl in Europe. This diminishes towards Poland, on the W., where it is 540 feet thick, and toward the Volga, on the E., where it is 200 feet thick.

4. Its palæontological contents show it to represent a facies which is not definitely Senonian or Turonian, but is a combination of both (Senonio-Turonian), and that the lithological variations (Chalk and Chalk Marl) have no effect on the character of the enclosed fossils.

Apparently, however, towards the W. the W. European conditions seem to be more nearly approached. No zones can be determined.

5. That the White Chalk and Chalk Marl have no absolute definite relation to each other (White Chalk being sometimes found both below and above Chalk Marl), but that in general the former overlies the latter.

6. That the Upper Cretaceous is unconformable to the Tertiary overlying it, and on its S. border rests successively on Archæan, Jurassic, Permian, Carboniferous, and Archæan.

7. That a great part of these deposits is overlain by Tertiary and Post-Tertiary deposits. (An important Phosphatic deposit occurs a few feet above the junction of the Tertiary and Cretaceous, extending through the Kharkoff, Poltava, and part of the Kieff and Kursk Governments.

8. That the Upper Cretaceous does not form one single synclinal basin, but is folded into several anticlinals and synclinals, which are then unconformably overlain by the Tertiary.

The above, then, are the main general points with regard to the Senonio-Turonian basin of S. Russia.

For the Cenomanian the following conclusions may be enunciated:

1. That in the largest number of cases where junction exposures are shown, it is found underlying the above-mentioned beds.

2. That borings prove it to underlie the Chalk and Chalk Marl at the points of their greatest depth (as at Kharkoff).

3. That lithologically it is mainly Greensand, and is on the average about 100 feet thick.

Of late years, however, new problems have come into the field, and new paths have been opened up. The "Challenger" expedition has thrown new light on the Ocean deposits of the present day, and once more interest is turning to that vast Chalk area which lies at our very doors. The homogeneity of the Chalk is fast becoming a myth of the past, and the microscope seems likely to help in unravelling something of the physical geography of that far distant period.

Hitherto, however, if we mistake not, the efforts in this direction have never been undertaken on a large scale, unless, perhaps, exception be made in the case of M. Cayeux's researches on the Senonian and Turonian of the Nord. The attack has in other cases been mainly made on Chalk containing more or less phosphatic material. The problems may be discussed perhaps a little as follows:

1. What are the actual residues left after solution of the calcareous portion of the Chalk?

2. How far may those fragments reveal their own origin, and so throw light on the causes which brought them into their present position?

The researches of M. Cayeux on the Dièves of Liege (Soc. Géol. du Nord. Annales, vol. xix. 1891, 2e Livr), may well serve as a basis for further experiment in this direction.

Statements, however, as to the contents of the Chalk residues in the Tchernigov Governments are to be met with in Professor

Armachevsky's paper on this district. He shows that the dried white soft Chalk is composed as follows:

CaO	55·46	The residue is clay and some quartz grains. These may sometimes form 1 per cent. of the whole, giving rise to a harder white limestone.
MgO	·12	
CO_2	43·70	
Residue	·41	
	99·69 per cent.	

Glauconitic Chalk also occurs in a few places, as at Rogovka; an analysis is as follows:

Mainly Coccolites and Foraminifera	CaO	36·57	*Residue* = angular grains of quartz (0·03 0·1 mm. diameter), about equal diameter, transparent. *Glauconite* = olive-green, and some evidently casts of *Textularia*, *Rotalia*, and *Nodosaria*. Also plates of Mica and clayey parts.
	MgO	Traces	
	Co_2	28·78	
	Residue	34·63	
	(acetic acid)	——	
		99·98 per cent.	

The presence of mica (muscovite), both in this Chalk and in the Chalk Marl to be mentioned below, is of special interest, as some of the Archæan rocks, about 100 miles distant, are very rich in this mineral, muscovite-granites with garnets being not uncommon.

The Chalk Marl differs but little from the above except in the large amount of residue it contains:

CaO	22·05—22·34	Composition of residue as above.
MgO	Traces	
CO_2	17·32—17·55	
Residue	60·00—61·14	

Had we been aware at the time of the interesting problems now opening up, we should have made a far greater collection of specimens of Chalk and Chalk Marl than is at present at our disposal, but Messrs. Winning have agreed to preserve specimens of the varieties of Chalk they may henceforth obtain from their borings, and if they should carry out their promise, great hopes may be entertained of considerably advancing our knowledge on these subjects.

As it is, we have brought with us examples of the Bielgorod soft White Chalk, the Kharkoff ditto (500 ft. from surface) Chalk Marl from Bielaia (800 feet down) and Chalk from Sviati Gori. Also a few specimens from the Kharkoff bore, which have not been labelled as to depth. These may serve as types, but will not be sufficient for the establishment of any broad generalization.

II.—Did the Mammoth Live Before, During, or After the Deposition of the Drift.

By Sir Henry H. Howorth, K.C.S.I., M.P., F.G.S., etc.

(*Continued from page* 258, Vol. IX. June, 1892.)

HAVING sifted the evidence in so far as it is available in Scotland and the North of England, we will now advance further south; and first in regard to the Eastern Counties. Here as elsewhere it is unfortunate that we so very seldom can find the beds upon which the solution of the problem depends in actual

contact so as to apply the only real test, namely, that of superposition. When we can do so, it seems to me the case is conclusive.

In Mr. Jukes-Browne's Survey Memoir on the eastern part of the county of Lincolnshire, there is only one section given in which the Pleistocene Mammals occur, namely, at Burgh. Here remains of *E. antiquus*, *R. leptorhinus* and *Bos primigenius*, or of Bison, were found in gravel *underlying* 3 to 6 feet of Boulder-clay and underlaid by a black turfy bed and by marl (*op. cit.* p. 86).

At Little Bytham, in the same county, Mr. Skertchly found *Corbicula fluminalis*, which marks the same horizon, under Boulder-clay.

We will now turn to East Anglia. Recent discoveries have tended to increase, rather than to solve, the difficulty of fixing the exact age of the Forest Bed. The discovery of remains of the Musk Sheep, of the Hyæna, the Glutton, all animals characteristic of Pleistocene times, seems to suggest either that the Forest Bed has been hitherto ante-dated; or that, like the Norwich Crag, it may consist of re-arranged or *remainé* materials. Whatever view may be adopted, there can be little doubt now that the Mammoth occurs in the Forest Bed. Dr. Leith Adams, writing in 1881, describes several molars found in it by Mr. Savin, which he unhesitatingly identifies as Mammoth, and he adds: "I can have no hesitation in admitting the Mammoth among the pre-Glacial mammals of the British Isles" (Pal. Mem. p. 174).

This last clause is no doubt a deduction from the fact that the Forest Bed, as exposed at Cromer, underlies the whole of the Drift deposits.

Mr. Austen, writing in the 7th volume of the Q.J.G.S., speaks of the beds of terrestrial origin, *i.e.* of the land surface exposed at Runton and Mundesley, and says the Mammalian remains found *in the overlying Till* have in every instance been derived from portions of the expanse of that former terrestrial surface (*op. cit.* p. 133).

Again, Professor Dawkins tells me one of Mr. Gunn's Elephant teeth from the Norfolk coast was striated and rubbed as if by glacial action.

It is in Suffolk, however, not in Norfolk, that the most interesting and critical test case is supposed to have been forthcoming, namely, the classical section at Hoxne first described by Prof. Prestwich in 1859, and which, for a long time, was accepted as conclusive, and is still the basis of the orthodox geological opinion about the age of palæolithic man. It seems to me that the conclusions based upon this particular instance will have to be surrendered. In the first place the sections given by Prof. Prestwich are most uncertain in their reading. Thus in the first and most important section *no bed of Boulder-clay is given at all.* In the section of the pit in which flint implements and Mammalian remains were actually found, *all the beds* contain fresh-water shells or peat, or Mammalian bones, and there is no trace of drift at all (see Phil. Trans. vol. 150, p. 305).

Feet.	
1 to 2 *a*.	Surface soil, traces of sand and gravel.
10 to 12 *b*.	Brown and greyish clay, not calcareous, used for brick-earth, with an irregular central carbonaceous or peaty seam. Two flint implements found in this seam the previous winter.
½ to 1 *c*.	Yellow rectangular flint gravel with some chalk pebbles and pebbles of siliceous sandstone quartz, and other older rocks. Bones of Mammalia.
3 to 4 *d*.	Bluish and grey calcareous clay in places very peaty, with wood and vegetable remains, land and fresh-water shells. Bones of Mammalia.
1 to 1½ *e*.	Gravel like *c*, but smaller and more worn, with more chalk pebbles.
f.	Calcareous grey clay more or less peaty, with fresh-water shells. Mr. Prestwich says he made a boring in this clay 17 feet deep without reaching bottom.

It is true that Mr. Prestwich and Sir J. Evans had some trenches dug in other parts of the field which showed the white and ochreous sands and gravels to be underlaid by a grey clay, but I altogether demur to treating this clay as boulder-clay. It seems to me to answer to the clay marked *f* in the big section in the pit. At a distance of 150 yards from this pit is another pit where Boulder-clay is dug, and here we are expressly told that no other beds were exposed (*id.* p. 307). Mr. Prestwich himself calls attention to the unsatisfactory character of the evidence (*id.*). The Boulder-clay caps all the hills around. Its very uneven base rests on white and yellow sands and gravel.

In 1876 Mr. Belt wrote an elaborate paper in the Quarterly Journal of Science, giving many sections of the ground at Hoxne, in which he sharply contested Professor Prestwich's conclusions, and avowed his opinion that the facts prove the implement-bearing gravel there to underlie and not overlie the Boulder-clay.

Lastly, let me quote my friend Mr. H. B. Woodward. In a paper read before the Norwich Geol Soc. he says: Mr. Belt recorded traces of Chalky Boulder-clay on the Hoxne beds, and my colleague Mr. Reid *and myself subsequently observed two tiny traces of this Boulder-clay on the brick-earth in the pit in the park* (Proc. Norwich Geol. Soc. pt. ii. p. 62). It having been suggested that these pockets of Boulder-clay were brought into their position by man, Mr. Reid writes "they seemed to have been there for a long while, for they were grassed over, and, if I remember rightly, an oak tree was growing on one of them (Mems. Geol. Surv. 50 N.S. p. 30).

It is clear therefore that when analyzed, the case so often quoted, and upon which such a stupendous induction has been based, utterly breaks down, and that the evidence there, if it points a moral at all, points to the actual reverse of the one maintained by so many geologists.

Let us, however, proceed further, and in the first place turn to another district in Suffolk, namely, the neighbourhood of Brandon.

Mr. Skertchly affirms positively, in one of the volumes of the Mems. of the Geol. Survey, that Early Palæolithic remains are found there in a series of loams, sands, and gravels *overlaid by chalky Boulder-clay*. "To this series," he says, "I have given the name of the Brandon beds. They are very fragmentary, but seem to occur pretty nearly all over East Anglia wherever the chalky

Boulder-clay extends, always cropping out at or close to its base, and never in a single instance occurring away from it. This remarkable association is only explicable on the supposition that the Brandon beds are older than the chalky Boulder-clay, and indeed that clay can be actually seen lying thick upon them, and often contorting them, sometimes for a mile at a stretch. Up to the present time they have yielded implements or flakes at Botany Bay (near Brandon), Mildenhall brickyard, High Lodge, Mildenhall, Bury St. Edmunds, West Stow, and Culford. The first discovery was at Botany Bay, and at the time no Boulder-clay was visible at the precise spot, but it has since been met with, and I had the pleasure of the experience of Mr. Amund Helland when this fact was made clear. At Mildenhall brickyard and High Lodge good thick chalky Boulder-clay overlies the Brandon beds, whence many implements have been obtained, and at Culford, whence I dug out a good flake, in company with Mr. F. J. Bennett, the Brandon beds are worked under 15 feet of chalky Boulder-clay, and can be traced beneath that deposit for the distance of a mile to the eastward" (Age of Palæolithic Man, pp. 67–69).

I ought to say that on a copy of this Memoir in the Jermyn Street Museum there is, in the handwriting of Professor Ramsay, the following note attached to a section: "Pit beneath Boulder-clay, opened for some years, and dug into again in 1878, where the flint implements were found, sent to the Museum by Mr. J. C. Maynard of Brandon" (*id.* p. 68).

In regard to the beds at Mildenhall, where Mr. Skertchly found his Palæolithic implements, Mr. H. B. Woodward, who has examined the locality carefully, says: "There was brick-earth overlaid by Boulder-clay. . . . . There was no escape from the conclusion that the brick-earth was older than the Boulder-clay. This bed of brick-earth, and other beds of brick-earth near Thetford, interested me much, for I had come across similar beds near Norwich, which were older than the Boulder-clay. Sir A. C. Ramsay, Mr. Bristow, Mr. Whitaker, and others, have now seen the sections described by Mr. Skertchly, and have agreed with him that the brick-earth, said to contain Palæolithic implements, is older than the Boulder-clay" (Proceedings Geologists Association, vol. ix. number i.).

Speaking of the gravels at Ipswich in which Mammalian remains have occurred, Mr. Whitaker refers to the difficulty of classifying the gravel and in dividing it from the like deposit of glacial age *against which it ends off*. He also speaks of the Boulder-clay having been *found at the surface* in the town itself (Geology of Ipswich, etc., p. 93).

Elsewhere he writes of finding pieces of bone or of Elephant's tusk, with shells, in a low cliff of buff sand and loam lying directly on London Clay (*id.* p. 95).

The horizon of the famous Mammalian deposit at Barrington in Cambridgeshire has been much discussed and it has been very dogmatically stated on more than one occasion that the beds are post-Glacial, meaning posterior to the deposition of the drifts. I cannot

see any evidence in this. The sections clearly show that the bone beds are overlain by trail as Mr. Irving himself admits (Q.J.G.S. vol. xxxv. p. 670), and they rest on the Greensand and Chalk-marl.

In the adjoining County of Bedford I know of no direct evidence of super-position, but inasmuch as a great deal has been made of such evidence as is there forthcoming by the advocates of the so-called post-Glacial date of the Mammoth and Palæolithic Man, it may be well to devote a few words to them and especially to the section at Biddenham.

Mr. Prestwich has given an admirable section of the deposits in the valley of the Ouse at this point (Q.J.G.S. vol. xvii. p. 364). From this section it seems that the valley of the Ouse has been scooped out of the Oolitic rocks known as Cornbrash. In the lowest portion of the trough so created runs the river Ouse, which has deposited a certain amount of alluvium along its course. On a higher level in the valley is the bed of gravel in which the flint implements were found. Lastly, the bounding heights of the valley on each side are capped with Boulder-clay, which stretches for miles in all directions (Lyell, *op. cit.*). The theory generally adopted is that the Boulder-clay was once continuous across the valley, and that the valley has been scooped out of it. This is the view of Mr. Prestwich, Sir J. Evans, Sir Charles Lyell, etc., etc.

One thing is clear, if the Boulder-clay once occupied the valley in this way the scooping out must have been most complete, and the floor of the valley laid bare; for as Sir Charles Lyell expressly tells us the two implements first found in the gravel were found "at the depth of 13 feet from the surface and rested immediately on solid beds of Oolitic limestone," and so he reprints it in his section. At this point, then, the evidence is plain that there is no superposition of the flint-bearing beds on the Glacial clay. The former lie directly on the floor of the valley, and such evidence as is forthcoming at this point is of an essentially secondary and deductive character and certainly does not warrant the assertion of Sir Charles Lyell, that the Bedford sections teach us that the fabricators of the antique tools and the extinct Mammalia coeval with them were post-Glacial (*id.* p. 217). But let us proceed somewhat further. In 1866 Mr. Flower described the discovery of flint implements, at Thetford, on the Ouse. These he tells us were obtained from 12 to 15 feet below the surface *and within a foot or less of the Chalk on which the gravel rests; and some were found in some gravel filling potholes in the Chalk* (Quart. Journ. Geol. Soc. vol. xxii. p. 567). Here the evidence carries our case still further, for not only does the gravel lie immediately on the solid rock, but also in the potholes; so that the sweeping out of the Boulder-clay must have indeed been complete and profound. Let us turn to another site in the same valley, namely, at Summerhouse Hill, where Mr. Wyatt found flint implements which had come from beds containing a similar assortment of Mammalian bones and land and freshwater shells to those found nearer Bedford. He gives an admirable section across the valley at this point showing a state of things precisely the same as in the sites already referred to (Quart. Journ. Geol. Soc. vol. xx. p. 185).

The Boulder-clay caps the ridges of Navesden and Hammer Hill, bounding the valley on either side; but within the valley itself, including the elevation of Summerhouse Hill, there is no glacial deposit. That Hill divides the valley into two troughs, in each of which the drift gravels with Mammalian bones and shells are found, and in each these gravels repose on the Oxford Clay and that on the Limestone of the Middle Oolite.

I am further bound to say that in Mr. Wyatt's section, published in the Geologist for 1861, page 243, and again by Mr. Prestwich in the Q.J.G.S. vol. xvii. p. 364, the Mammal and Implement bed at Biddenham appears to be overlain by drift.

Turning from Bedfordshire the only discovery of interest in Central England in the present discussion was made in Hertfordshire.

Professor Prestwich, writing in 1858, says: "A ballast pit has recently been opened at the Watford end of the Bricket Wood cutting, and immediately south of the line, which exposes a section of much interest. The Boulder-clay has there almost thinned out, leaving but a seam one or two feet thick, whilst above and below it is a thick bed of gravel. . . . The lower gravel I believe to pass under the Boulder-clay. . . . In the ballast pit I was fortunate enough to discover in the lower gravel a few pieces of the tooth and tusk of the Elephant. . . . The lower gravel reposes upon an irregular surface of chalk (Geologist, 1858, p. 242).

Let us now turn to the Welsh caves.

Dr. Buckland says that in 1836 he found, on the property of Mr. Lloyd near Cefn Cave, fragments of marine shells associated with the usual detritus, and inferred from the fact of Mr. Trimmer and Dr. Scouler having discovered recent marine shells and drifted pebbles over the bones in the cave, and from the admixture of the bones of mammifers with diluvium in Kirkdale, Torquay, and other caverns, either that these caves were submerged subsequently to their having been inhabited and again raised above the level of the sea, or that vast irruptions of water, apparently loaded with icebergs, had overwhelmed the country (Proc. Geol. Soc. vol iii. p. 584).

Making allowance for the geological language which then prevailed, this means that so far back as 1836 Dr. Buckland had affirmed that the Mammalian bed in the Cefn Cave was overlain by drift.

Mr. D. Mackintosh, in speaking of the Cefn and Pont Newydd Caves, refers to the clay in the cavern as containing angular and subangular fragments of limestone, a few polished fragments and pebbles of limestone, and a few pebbles of Denbighshire sandstone and grit, felstone, etc., and he says: "It is horizontally continuous with the Upper Boulder-clay of the district. The clay, he says, can be traced along the plain of Lancashire and Cheshire, the coast of Flintshire, and up the Vale of Clwyd. It spreads over the gently rising ground between St. Asaph and the Cefn and Pont Newydd Caves, and it may be seen all round the caves, in some places filling up hollows, in others covering plateaux, and in not a few instances clinging to the face of steep slopes, or even adhering to narrow rock terraces or ledges. I have been familiar

with this clay in Cheshire and Flintshire for four years, and have therefore little hesitation in asserting that traces of it, in an unmodified state, may be found at the entrances of both the Pont Newydd and Cefn Caves, that in the interior of the Cefn Cave, for a considerable distance from the entrance, there are indications of this clay once having filled the cave nearly, if not quite, to the roof, that in the interior of the Pont Newydd Cave it maintains its unmodified character for a considerable distance from the entrance, and that in no part of these two cases has this clay been modified further than what may have resulted from the dropping of calcareous matter, from the temporary pounding back of water in the recesses or hollows, or from accumulations within the caves under conditions which may have differed from those without" (Q.J.G.S. vol. xxxii. p. 92).

Let us now turn to another case.

The Cae-Gwyn Cave has acquired a great notoriety in this controversy. The evidence it furnishes seems to me to be clear and conclusive, that the Palæolithic remains were there overlain by glacial deposits at 135 feet from the entrance. As early as 1885, sand, like true marine sand, was found overlying the Bone-bed and laminated clays. This sand was examined in that year by Professor Dawkins, who says, "I have carefully compared the sand and gravel found in the upper cave Cae-Gwyn and mud sometimes adhering to the bones with the glacial sand and gravel which occurs in the valley a little way above, and find that in every particular they agree. I have also compared them with the glacial sands and gravels near St. Asaph and find that all three are composed in the main of quartz, quartzites, and Silurian fragments" (Q.J.G.S. vol. xliv. p. 562).

In 1886 further excavations took place, and a section was exposed in which the bone earth was found to be overlain by laminated clay, sand, and gravel, this again by clay with boulders and bands of sand and gravel and this by soil (*id.* p. 563). The various sediments in the cavern, says Dr. Hicks, retained their relative sequence throughout and this sequence was continued uninterruptedly from the cavern into the drift section on the outside (*id.* p. 566).

In this reading of the evidence, Sir A. Geikie, Mr. De Rance, Mr. Tiddeman and Mr. C. Reid concurred. Mr. Morton says: In June last during the progress of the excavation in front of the original entrance to the Cae-Gwyn Cave I stayed at the inn close by for eleven days. From the first time I saw the section I felt convinced that all the beds were strictly *in situ* . . . The laminated clay had evidently been tranquilly deposited over it (the bone earth), the sand and gravel were over the laminated clay, but current-bedded as such so-called 'Middle sands' often are. Finally, the Boulder-clay occurred over the sand and gravel without any evidence of disturbance or rearrangement whatever. . . . . The Boulder-clay appeared to me as good an example of undisturbed clay as anywhere in the Vale of Clwyd, Cheshire, or Lancashire, while the Erratics are very similar . . . if it were to be considered post-Glacial we should have no Glacial deposits in the district . . . the remains of Mammalia

found in the bone-earth were evidently deposited in the cave before the deposition of the Boulder-clay, and there are no indications of any interglacial period between it and a still earlier period of land glaciation (*id.* pp. 571–2). Dr. Hicks says, "The recent researches at Cae-Gwyn have proved most conclusively that there was no foundation for the views of those who contended that the drift which crossed over the entrance and extended into the cavern was remainé and had gradually crept down the hill. They have shown beyond the possibility of doubt that the deposits which overlie the true earth are *in situ* and are identical with the typical Glacial deposits of the area. . . . The excavations carried on in 1885, 1886 and 1887, show that the caves must have been occupied by the animals before any of the Glacial deposits now found there had accumulated (*id.* p. 575). Mr. De Rance writes, June, 1886, "the entrance to the cavern had been discovered and a vertical shaft 20 feet deep, disclosed Boulder-clay resting on drift sand which passed continuously into the cavern itself, while the underlying bone-earth similarly passed outside the cavern and formed the base of the cutting as far as it was carried. In June, 1887, the pit in the drift was cut still further back, the bone-earth still continuing to form the base of the Glacial drift" (*id.* p. 576). "Mr. Strahan believed that the drift of the mouth of the cave was part of the northern drift which he had mapped over a large part of Denbighshire, Flintshire and Cheshire, and that the bone-earth lay beneath it" (*id.* p. 577).

In the discussion on Prof. Hughes' paper in the Q.J.G.S. vol. xliii. on the drifts of the Vale of Clwyd, Dr. Hicks said the Arenig drift is known from well-sinkings to be underlain by sands and gravels like those at Talargoch, in which bones of animals, similar to those found in the caverns, have been discovered. He said further, that he was perfectly convinced by the evidence found during the exploration of the caves of Ffynnon Beuno and Cae-Gwyn that they must have been occupied by man and the animals before the climax of the Ice-age, and that the mammalian remains and the implements must be considered as of pre-Glacial age. Professor Dawkins said that after examining the first section he felt obliged to accept Dr. Hicks' evidence. The drift above the place where the implements was found was, in his opinion, not *remainé* but *in situ*; with regard to the mammalia found in the caves of the Vale of Clwyd, nearly all were living in the eastern counties in the pre-Glacial age" (*op. cit.* pp. 116–118).

Prof. Prestwich, in 1887, in abandoning his earlier view, which was against the existence of pre-Glacial Man, said that the cave work of Mr. Tiddeman and Dr. Hicks gives strong presumptive evidence of the earlier geological appearance of Man in the British area; and he saw no reason to doubt the sub-Boulder-clay evidence of Mr. Skertchly. Of the correctness of his opinion in regard to the stratigraphical position of the bed in which his specimen was found, I have, however, little doubt (Q.J.G.S. vol. xliii. p. 406–7). In the discussion which followed, Mr. De Rance said he quite agreed with Dr. Hicks in his interpretation of the facts observed by him (*id.* 409).

In the Hyæna-den, near Ross, situated 300 feet above the present

Wye, Mr. Symonds found a stratified red sand and silt, 3 or 4 feet thick, containing pebbles, one of which was greenstone; and he adds: "Every one of those pebbles out of that red sandy deposit must have been derived from Silurian and Trap rocks which are not to be found *in situ* until after we have traversed the long tract of Old Red Sandstone through which the Wye passes between Coppel Wood Hill, near Ross and Trewerne, above Hay or Breconshire, a distance, by the river of 70 or 80 miles" (Geol. Mag. Vol. VIII. p. 436).

The evidence of this cavern therefore completely supports that from North Wales.

If we now leave the area where true Glacial drift is supposed to occur and enter the Thames Valley, the evidence seems to me to be equally conclusive.

In the Thames Valley Boulder-clay is not found, but I suppose it is generally agreed now that the Trail of Mr. Fisher represents it. Now, there can be no doubt that this Trail overlies the Mammalian and Palæolithic gravels of the Thames Valley.

Dr. Falconer, in discussing, in 1857, the deposits at Gray's Thurrock, and the lower beds at Brentford, in the Thames Valley, "inferred that they were of an earlier age than any part of the Boulder-clay or Till" (Q.J.G.S., vol. xiv. p. 83). "It appears," says Mr. Symonds, "that these Thames brick-earths are covered by a Glacial deposit of ice-borne *débris*, as is the Forest Bed by Boulder-clay" (Geol. Mag. Vol. V. p. 420).

Professor Boyd Dawkins, in his paper on the age of the Lower Brick-earths of the Thames Valley in 1867, gives a section from the Uphill Pit at Ilford, in which the famous head of the Mammoth now in the British Museum was found. The bed in which it occurred was covered by several beds of loam, clay, gravel, and sand, of one of which Professor Dawkins says: "By the comparison of its bedding, the admixture of clay with sand and gravel, and the presence of pebbles of chalk and of large transported boulders of grey weathers and of flint, is proved beyond doubt to be of Glacial origin—to have been carried down by the ice and deposited on its melting, upon the eroded top of the fluvatile deposits below." In regard to Mr. Prestwich's notion that the bed was partially formed from gravel derived from the Boulder-clay, Mr. Dawkins says, "a careful examination compels me to believe that there is no proof of the derivation of this Glacial deposit from the wreck of the Boulder-clay" (Q.J.G.S., vol. xxiii. p. 93). Turning to Gray's Thurrock, he argues that we have precisely the same superposition, there being bed numbered 6 on the section which from the irregular size of its pebbles, its tabular flints, its contortions, and its irregular deposition, owes its presence to ice in some form or other. Its sandy nature may be owing to the Thanet sand having been caught up by the ice and deposited on its melting, just as the clayey nature of the Trail at Ilford was probably owing to portions of the London Clay being in like manner transported (*id.* p. 95). This bed was distinctly superimposed on the gravel containing Mammalian bones. At Crayford he gives a section in which a similar bed, number 7, consisting of an irregular

reddish-sandy contorted stratum, full of large flints both angular and water-worn, and of quartz pebbles, and confusedly bedded, is found in just the same situation as the drift beds above named (*id.* p. 96). At Erith, Mr. Dawkins discusses an interesting section, in which he found the same superposition; and he specially remarks upon the presence of a large block of black clay, with its angular shape preserved, which had been transported about 150 yards and deposited in the Trail, and says of it: "It is altogether impossible that this angular mass of clay could be transported more than 150 yards, preserving its angularity, and deposited in such a matrix, by any other agency than that of ice. The tract here was highly contorted, contrasting much with the horizontal beds below it" (*id.* p. 98). He concludes that the beds at the several points described are contemporary, and that they establish that after the temperate conditions marked by the Mammalian remains, they were followed by a period of intense cold, in which stones, sand, clay, and indeed whatever came within the reach of the ice in the neighbourhood, was caught up and deposited in a most confused jumble on its melting (*id.* p. 99); and in summing up the case he puts the Lower Brick-earths of the Thames Valley distinctly below the Glacial beds (*id.* p. 109).

In discussing Mr. Dawkins's results, Mr. Marr, in the Geological Magazine, suggests that the beds of the Thames Valley containing transported materials may be an inland extension of the Boulder-clay *on the same level* (*op. cit.* vol. iv. p. 100).

Lastly, we have the most recent discovery of all, so lately discussed before the Geological Society by Dr. Hicks, where an old land surface containing considerable unweathered remains of the Mammoth was found in the heart of London reposing directly on the London clay, overlain by a clay containing drift from Hertfordshire, and filled with chalk, which Dr. Hicks, as I think, most conclusively correlates with the chalky Boulder-clay.

I have now examined every instance known to me where it is possible to test by superposition the question of the relative age of the Mammoth beds and the Drift in the British Isles, and I claim to have shown that, as tested by these islands, the Mammoth beds are in every instance overlain by the Drift, and are never underlaid by it. I propose in another paper to consider how far this conclusion is supported by the evidence from foreign countries.

III.—On Rapid Elevation of Submerged Lands and the Possible Results.

By Rev. E. Hill, F.G.S.
Late Fellow and Tutor of St. John's College, Cambridge.

IT is not impossible that readers of a paper lately published by our venerated senior geologist may have been startled, some for one reason, some for another and opposite. On reading the suggestions he has put forward as to the results from rapid elevations over southern England, some will recoil as at a revival of catastrophic machinery; some on the other hand may hail the invention of a

novel and most potent agency. I doubt whether either view is altogether correct or defensible.

In the paper referred to (Q J.G.S. vol. xlviii. p. 332) there is quoted a discussion by Mr. Hopkins on the results from "paroxysmal elevations" of areas at the bottom of the sea. The writer himself, however, says that he is contemplating "not such great changes and powerful [resulting] currents," but still, movements of this character in which "the uplift was rapid." "It is evident," he says, "that we have in this form of disturbance an engine of enormous power." The phenomena called the 'Rubble Drift' of southern England, he suggests, may have been produced by currents of water pouring off from areas "rapidly uplifted." The areas uplifted are to be variable and uneven land-surfaces. The amounts, however, of uplift are not indicated clearly, and the degrees of rapidity not at all. What amounts of elevation are contemplated, and what ratio would be regarded as 'rapid'?

Darwin records sudden elevations in Chili to the extent of ten feet (Nat. Voyage, chap. xiv.). Lyell mentions a subsidence reaching forty feet; but the area was small, and subsidence is a much simpler matter than elevation. I think that twenty feet may be regarded as a considerable height through which to 'rapidly' raise even a few counties along the coast. 'Rapidly' it must be remembered is a relative word. Light is rapid compared with sound; its velocity being nearly a million times as great. A cannon ball is also rapid compared with a snail: if a snail's pace be an inch per minute the one is also about a million times the other.

But the rates of elevation which have been measured in Scandinavia and elsewhere are such that to change them into the pace of that snail would be a greater multiplication of speed than that required to make the snail gallop alongside the cannon ball. In an old jesting problem of our childhood, a snail was set to climb twenty feet of wall at the rate of two feet per day. Accelerate his pace so that in six hours only he can climb the whole twenty feet; to change his pace into that of a cannon ball would require no greater change than the change that would lift Scandinavia through twenty feet in six hours. Would not this be a 'paroxysmal' change?

Again, the force required to produce such elevation would be prodigious. We know, indeed, little of the forces at work under the earth's crust, but is any force we are acquainted with able to produce a respectable fraction of such a result? Most violent Japanese earthquakes exhaust their potency in vibrations measured by inches or by less. What must be the violence which could permanently uplift a country several feet! Mr. Whymper saw Cotopaxi eject a mass of ash which he calculates at two million tons or more. This enormous mass was shot up to a height of 20,000 feet in a single minute.[1] But the work so done would not suffice to uplift the mere surface soil of an English county through a single

[1] Travels among the Great Andes of the Equator, p. 328. I am not sure whether he means that the whole operation was completed in a minute. If not, the force in action was less than I am assuming it to have been.

yard. Suppose that the power which did this prodigious work within one minute, instead of exhausting itself in that minute should continue with unabated violence for six long hours. In those six hours it could have uplifted a mass of rock, in depth a mile, under the surface of an English county, through less than a couple of inches. The multiplications to obtain an adequate force are not quite so immense as those required for the rate, but would suffice to make a mouse as strong as an elephant. Besides, here we are making comparison with paroxysms. The mouse is itself a mountain in labour. Cotopaxi in eruption must be magnified by a power of ten thousand. No such force then would be capable of uplifting southern England through several feet even in a whole day. Accordingly, we seem justified in regarding an elevation of twenty feet within six hours as an elevation effected with very great rapidity according to any reasonable use of the word. Most, indeed, would regard such action as paroxysmal and catastrophic. But, whether so or no, there is not the slightest doubt that the effects produced by the water as poured off from the land so elevated would not be catastrophic. Such effects are not rare but common. They are matters of daily experience. More even than that, they may be seen produced, over a large area, on a large scale, twice in every day. Twice in every day for hundreds of miles along our coasts the level of the land compared with the sea rises some twenty feet or more in six hours, and twice in every day it again falls, through the same space and in the same time. True, this is due to alterations in the sea level, not in the land, but *as far as regards the flow of waters off from or on to the land* the effects must be precisely the same. The action of waters pouring away from a rising land can be seen, can be studied, can almost be experimented upon, twice daily in the Tides.

The tides along most of our southern and western coasts give us the results of elevations up to twenty feet or more. In Jersey we can examine elevations up to thirty feet; at Chepstow up to forty; those who can travel as far as the Bay of Fundy will perhaps be able to see what seventy feet could do. Thus, on the one hand, the effects of the supposed exceptional agency would not be exceptional, but common ordinary effects; and on the other hand, it does not seem necessary to invoke such exceptional agency; for if the effects be produced by it, then the daily work of the tides is capable of producing daily the same sort of effects. "In the case [considered in the paper] the area of elevation consisted of a variable and uneven land surface," such a surface as is alternately covered and exposed in the archipelago of the Channel Islands. "Each hill or group of hills formed a centre for the diverging currents," as in that archipelago each islet, shoal, or group of rocks, for the ebb and flow of the tide. "The velocity of [these currents] would further vary according to the varying gradients and lengths of the slopes," but much more according to the conformations of the subaqueous channels. "Where the sediment is fine we may conclude that the velocity was slow, and the rise which gave origin to it small.

Where, on the contrary, the materials are coarse, we may suppose the rise to have been more rapid and the velocity of the current greater. When, again, large blocks have been transported, a more energetic movement is made manifest." What rate of tide-run is sufficient to move about "large blocks"? "Some indication of the duration of the uplift is afforded by the mass of material moved, and the distance traversed." Comparison with observed effects of tides seems to show that to move large blocks the duration must be very short if the uplift be moderate, or the uplift extremely great if the duration be moderate. The tides also teach that high speeds are generated only in confined channels. The water pours through the Swinge, the Race of Alderney, the Gouliot Pass, or the Sound of Lihou; but in the open bay of St. Aubin's a thirty feet fall does not create any remarkably strong current off the shore.

There are two classes of catastrophe whose effects have probably magnified our ideas as to the potency of rapid rises or falls. When reservoirs or other dams burst, as in the St. Gervais calamity lately filling the newspapers; when earthquake waves roll in on to the land, as after the Krakatao eruption, direful disaster has been wrought. But neither catastrophe is properly comparable with the cases we have been considering. A reservoir is usually hundreds of feet above the sea-level. If its dam gives way the water flows off down this distance: the results, therefore, are analogous to what would happen if the land were elevated these hundreds of feet *instantaneously.* The earthquake wave, too, sweeps up the shore at a rate far exceeding what we can call 'rapid'; it rises its thirty or forty feet in a few seconds. Also its analogies belong to the case of a sinking, not of an uplifted, land.

We accordingly conclude that the effects of 'Rapid' emergence of land from below the sea will not differ from what we see happening daily between high water-mark and low, unless the rapidity is vastly greater than twenty or thirty feet in six hours; whilst even this moderate rapidity far transcends the powers of any agents with which we are at present acquainted.

IV.—The So-called Serpentines of the Lleyn.

By Catherine A. Raisin, B.Sc.

In the south-west of the Lleyn peninsula, the country inland is generally covered by drift, but the Survey map marks some isolated patches of rock as "Serpentine." When I first visited the district, with the kind encouragement of Professor Bonney, under whom I was continuing my work at University College, I made a collection of these so-called "Serpentines" from ten different localities. The one at Porth din lleyn had been shown by Professor Bonney to be mainly diabase,[1] and others of the examples have been since described in a previous number of this Magazine

[1] On the Serpentine and associated Rocks of Anglesey; with a Note on the so-called Serpentine of Porth din lleyn. By Prof. T. G. Bonney, Q.J.G.S., 1881, vol. xxxvii. p. 48.

and elsewhere,[1] but we have yet no complete account. I have, therefore, attempted to give a short summary, as preliminary to some discussion of the district.

In four of the exposures the rocks, which are much alike, are recognised as diabase by Mr. Harker. Although abstaining from any definite opinion of their geological position, he notices certain characters, in describing rocks, which, in eastern Carnarvonshire, are shown to be of Bala age. Masses from near Pwllheli and from other parts of the county certainly present much resemblance: and the four examples which I am considering might very well be intrusions along a N.E. to S.W. line, roughly in the direction of the strike or a strike fault. Lithologically they consist mainly of an ophitic dolerite undergoing a process of uralitisation, but the bosses also include more compact varieties, and many parts of the rock exhibit secondary changes due to crushing or development of minerals (often epidote).

1. *Trefgraig.*[2]—At least three varieties are shown in the quarry. (*a*) An ophitic dolerite, the felspar being somewhat decomposed, colourless augite, clear and well-preserved, occurring in one slide, in another a pale greenish hornblende. The latter mineral includes fibrous alteration, products and added growth, which sometimes surround a central core with a different crystalline orientation. Ilmenite is developed in the usual form of bars like sagenite. (*b.*) A finer-grained microporphyritic diabase. Veins which occur in the slide in some cases cross a felspar crystal, cementing it with felspar. A structure of this kind is attributed by Mr. Harker to infiltration along a line of "maximum shearing strain."[3] In the Trefgraig slide, however, the felspar of the vein, containing only very minute enclosures, contrasts sharply with the more decomposed substance of the original mineral. Each boundary is marked by bending of the crystal planes, and we should expect that any infiltration would have spread beyond this line. Again, although other parts of the vein are filled with serpentinous mineral, it seems at some places where it heals up broken augite to consist of felspar. (*c*). A fine-grained devitrified basalt or andesite, which contains a few slightly larger microliths of felspar and augite. It is associated with the dolerite first described, into which it seems to intrude, the larger crystals of the coarser rock being apparently snapped and sometimes crushed along the boundary line.

Some evidence of mechanical disturbance can be traced in the Trefgraig mass, and one specimen from near the edge is much crushed.

2. *Hendrefor.*[4]—The rock appears to be a uralitic diabase, retaining

[1] Notes on the Igneous Rocks of Lleyn. By J. V. Elsden, 1888, GEOL. MAG. Decade III. Vol. V. p. 303. The Bala Volcanic Series of Carnarvonshire and Associated Rocks. By A. Harker, 1889, Cambridge, pp. 83, 86-88, etc.

[2] The Monian system of Rocks. Rev. J. F. Blake, Q.J.G.S., 1888, vol. xliv. p. 531. The Bala Volcanic Series. A. Harker, pp. 83, 87.

[3] The Bala Volcanic Series of Carnarvonshire. A. Harker, p. 26. See also Q.J.G.S., 1889, vol. xlv. p. 253, fig. 4.

[4] Mr. J. V. Elsden, *loc. cit.* p. 304. Mr. A. Harker, *loc. cit.* p. 87.

traces of ophitic structure, some of the hornblende being bluish-green and very dichroic. In one brecciated example, granular epidote is scattered abundantly over the slide, replacing crystals and forming veins.

3. *Tyhen.*[1]—A specimen better preserved apparently than those examined by Mr. Elsden consists of fairly clear felspar and augite with an intimate ophitic structure, and contains some viridite patches marking probably another pyroxenic or allied mineral. Ilmenite and pyrite are present. A much more compact rock appears to be enclosed within this fine dolerite, probably intruding into it, as at Trefgraig and Methlan.

4. *Methlan.*[2]—A diabase or ophitic dolerite with some alteration products. A compact dyke ($1\frac{1}{2}''$ wide) is exposed by the side of the road.

Of the next four masses, two are described by Mr. Harker as including decomposed basalts.[3] The Careg Fawr crag is comparatively small and uniform, but at Porth din lleyn, as has been shewn, and also at Careg, a more complex mass occurs. Some examples from the latter place, like a specimen from near Hendre uchaf, show more pronounced microlithic development, but at all the localities we find a compact rock now altered, doubtless once glassy and of basic or fairly basic composition.

5. *Porth din lleyn.*—We are indebted to Professor Bonney for the description of these agglomerates and diabases, and for an examination which proved the absence of serpentine in this part of the Lleyn.[4] He described the rocks on the eastern coast of the promontory, and noted on the western side a similar diabase cut by amygdaloidal doleritic dykes, doubtless, as suggested, of later date.[5] Certain varieties are porphyritic, containing brighter green felspars within a dull green matrix. The ground mass in two rocks,[6] although they are not entirely identical, shows under the microscope many of the characters which occurred in certain specimens described by Mr. Elsden.[7] In one slide, epidote not only replaces crystals, but small rounded amygdules consist partly of that mineral, partly of viridite and of calcite. The porphyritic felspars are decomposed and saussuritic, often averaging $\frac{1}{4}''$ in length. They form one point of likeness between these rocks and a specimen which I obtained further southward in the Lleyn. The well known Lambay porphyry also bears some resemblance in the character of

[1] Mr. J. V. Elsden, *loc. cit.* p. 304. Rev. J. F. Blake, *loc. cit.* p. 531. Mr. A. Harker, *loc. cit.* p. 87.

[2] Mr. J. V. Elsden, *loc. cit.* p. 304. Mr. A. Harker, *loc. cit.* p. 87.

[3] Mr. A. Harker, *loc. cit.* pp. 87, 88.

[4] Q.J.G.S., 1881, vol. xxxvii. pp. 48-50. Prof. T. G. Bonney.

[5] Q.J.G.S., 1881, vol. xxxvii. p. 50. Prof. T. G. Bonney. Compare also Q.J.G.S. 1888, vol xliv. p. 461. Mr. A. Harker. The Bala Volcanic Series of Carnarvonshire. Mr. A. Harker, p. 111; GEOL. MAG. 1880, Vol. VII. p. 457. Mr. A. S. Reid.

[6] One of the rocks was obtained from a boss on the grassy slope and has a bright green polished surface with streaks coloured by red halmatite. Sheep are continually rubbing themselves against the projecting stone, and the polishing is evidently due to their action.

[7] Mr. J. V. Elsden, *loc. cit.* p. 308.

its ground mass and of certain of its porphyritic felspars, although others differ somewhat in their narrower longer shape.[1] One of the Porth din lleyn examples occurs in the cliff of a small cove beyond the boat-house, as if it were a broad dyke; and a tangle of rocks on the beach suggests that the porphyritic greenstone has enclosed within it a compact diabase. Even in this case the intruding mass need not be of much later date, but might belong to the same volcanic period. This remark also applies to another rock at Porth din lleyn, which is a fairly typical basalt, dark purplish or black and microcrystalline; it appears to be similar to a mass on the beach at Porth wen, probably a dyke. On microscopic examination the latter exhibits lath-shaped felspars, much magnetite and some viridite. Further examples of this type occur to the south.

A junction with schists is mentioned by Mr. Elsden, but I could find no true metamorphic rocks. Schistose masses occur, the exact nature of which, in many cases, is extremely doubtful, but I have identified among them rocks of igneous origin. One slide proves that a diabase was veined by calcite, and that vein stuff and igneous rock were crushed together, so that the original character is masked; but amygdaloids and microliths of the ground-mass can still be recognized.

One rock of interest is exposed at low tide on the face of the promontory beyond the boat-house. It is a whiteish, sub-crystalline limestone, partly a breccia, the fragments of which project on the weathered fawn-coloured surface. The microscope slide seems to have the structure of limestone rock, apparently dolomitised, rather than of mineral vein, traversed, however, by clearly marked secondary veins of calcite and of quartz. Some rather dusty or silicified enclosures, which occur, seem to me to be not organic but of igneous origin. So the precipitation of the calcareous material may have been contemporaneous with volcanic eruptions.

6. *Careg Fawr* (South of Aberdaron).—Of this I need say little, as Mr. Harker has fully described all its important characteristics.[2] My slides do not happen to show any indications of a perlitic structure, but exhibit some of the larger cracks, which can be seen in the field sometimes limiting spheroids. The crag stands squarely up from the more level ground, as Mr. Harker states, like an intrusive mass; but it need not therefore belong to a later geologic period.

7. *Careg* (North of Aberdaron).—At this place, thick veins or masses of jasper are found, and limestone also occurs, but it is close to a small outcrop of the schistose rocks of the district. The dull purplish or greenish bosses and crags, which are doubtless those called "serpentine,"[3] are certainly igneous, apparently rather basic, and some originally glassy in character. At places spheroids can be

[1] I am much indebted to Mr. Thos. Davies, F.G.S., for kindly allowing me to see slides of the Lambay porphyry, and other Irish specimens, in the collection of the Mineralogical Department at the British Museum of Natural History.

[2] Mr. A. Harker, *loc. cit.* pp. 87, 88.

[3] The Geology of North Wales. Mem. of Geol. Survey, p. 230 (2nd ed.)

recognized, which are often shiny and palagonitic at their exterior. In small quarries and knolls on the western face of the hill, the rock is a green and purplish breccia. Although it presents some resemblance to an agglomerate, I am doubtful whether this is the true explanation. Many of the purple fragments are parts of spheroids, or are spheroids which are fissured, with the fine greenish matrix filling the interspaces. The microscope slides and the hand specimens prove a fluidal structure, certainly within, and probably outside, the small fragments, which even include some ordinary brown tachylite. I believe that a second movement of lava took place breaking a mass partially consolidated. This might have occurred within the pipe or neck of a small vent, but it is probable that the mass represents, at least in part, lava which flowed at the surface. At the top of the hill the rock is less disturbed, and consists, as shown by the microscope, of lath-shaped felspars within a matrix containing very minute augite, magnetite, and other incipient crystals. Thus we find at Careg gradations from tachylite to a micro-crystalline condition.

At one place on the eastern slope above the house is a green diabase with green porphyritic felspars. Ilmenite crystals glisten on the surface, and the slide exhibits the characters of a fine-grained dolerite, with decomposed felspars, very fresh white augite, and a constituent now green and serpentinised. The rock is doubtless intrusive and may be of later age.

8. *West of Hendre-uchaf.*—The patch of rock shown on the word Cil y bwth was probably exposed in a quarry, now completely grassed and marked only by a curve in the sloping ground; and the outcrop near Bachwen I also failed to see.

West of Hendre-uchaf I obtained specimens of an old basalt or diabase, compact in structure, with patches of purple and greenish colour. Microscopic examination shows the darker part to consist of lath-shaped felspars amid a black deposit of magnetite. The felspars exhibit a somewhat spherulitic grouping at places especially within the ferruginous aggregates. Small porphyritic crystals, often fractured or incomplete, slightly dichroic, yellow in colour, now serpentinised, are probably a hydrous ferro-magnesian silicate. A similar mineral forms small acicular or shuttle-shaped microliths.[1]

The rocks in the two remaining examples are clearly clastic.

9. *North of Braich anclwog.*—(Annelog). This small patch is a purple and green agglomerate. The rocks included, as seen on examination with the microscope, are basalt or andesite, consisting chiefly of felspar microliths, with more or less viridite or magnetite. Pyrite and secondary limonite occur. The pieces are rounded or sub-rounded, separated by palagonite; and calcite is deposited both within and between them. In the small quarry, the fragments are of no very great size, the larger being about six or seven inches

[1] See figures in Brit. Petrog. J. J. H. Teall, p. 14 (after Zirkel); U. S. Explorations of 40th parallel. Microo. Petrog. F. Zirkel, pl. i. fig. 20; Typical Forms of Crystallites. F. Rutley. Min. Mag. Dec. 1891, p. 268, fig. 17. Crenulites.

across. There is apparently no stratification, and the mode of occurrence seems to mark this as a small volcanic vent.

10. *North of Mynydd anelwog.*—(Annelog). The low crag near the spring consists of an ash, finer than, but of very similar materials to, the agglomerate just described. Fragments of andesite or basalt are almost identical with the constituents of the preceding specimen, and those of green viridite might be derived from the same source, while occasionally a piece of scoria occurs. The fragments as seen by microscopic examination are small, with slightly irregular outline, and separated by strings of fine dust.

Thus all the patches of "serpentine," except the two mentioned, have now been examined, with the result that not only is there no serpentine present but there is no uniformity in their character, and I shall be able to show that similar rocks occur at many other places in the neighbourhood. Sometimes these "serpentines" are dolerites or compact diabases (andesites or basalts); sometimes they are true volcanic agglomerates. Although, in many cases, they are not interbedded, some probably represent lava flows, or an ash of transported fragments. This result, therefore, further illustrates the characters, which were first described by Professor Bonney from Porth din lleyn. His paper thus gave the key-note to the understanding, not only of that locality, but of others. The question of the geological age of these masses can only be discussed in connection with the surrounding district, since it affords additional examples of similar and allied rocks.

NOTICES OF MEMOIRS.

I.—British Association for the Advancement of Science. Sixty-second Meeting, Edinburgh, August 3rd, 1892. President, Sir Archibald Geikie, LL.D., D.Sc., For. Sec. R.S., F.R.S.E., F.G.S., Director-General of the Geological Survey of the United Kingdom.

Titles of Papers Read in Section (C), Geology, August 4–10.

Professor C. Lapworth, LL.D., F.R.S., F.G.S., President of Section.

The President's Address.

O. W. Jeffs.—Report of the Committee on Geological Photographs.

J. Lomas.—On the Glacial Distribution of the Riebeckite-Eurite of Ailsa Craig.

Dr. H. W. Crosskey.—Report of the Committee on Erratic Blocks.

J. W. Gray and *P. F. Kendall.*—The Cause of the Ice Age.

W. A. E. Ussher.—The Granites of Devon and Cornwall.

Dr. A. Irving.—The Malvern Crystallines.

J. G. Goodchild.—The St. Bees Sandstone and its Associated Rocks.

H. Woods.—The Igneous Rocks in the Neighbourhood of Builth.

A. G. C. Cameron.—Note on a Green Sand in the Lower Greensand, and on a Green Sandstone in Bedfordshire.

A. G. C. Cameron—The Fuller's Earth Mining Company at Woburn Sands.

C. E. de Rance.—Report of the Committee on the Circulation of Underground Waters.

B. N. Peach.—On a Widespread Radiolarian Chert formation, Arenig Age, in Southern Uplands of Scotland.

J. Horne.—On the Contact alteration of the Radiolarian Chert, along the margin of the Loch Doon Granite.

Dr. H. Hicks.—On the Grampian Series (Pre-Cambrian Rocks) of the Central Highlands.

J. F. Blake.—On the still-possible Cambrian Age of the Torridon Sandstone.

Prof. A. Blytt.—On some Calcareous Tufas in Norway.

Dugald Bell.—Alleged Proof of Submergence in Scotland during the Glacial Epoch. I. Chapelhall, Airdrie.

Dugald Bell.—Alleged Proofs of Submergence in Scotland during the Glacial Epoch. II. Clava and other Northern Localities.

Clement Reid.—Fossil Arctic Plants found near Edinburgh.

H. Coates.—The cuttings of the Crieff and Comrie Railway. Exhibition of Geological Specimens, Maps, and Photographs.

Prof. E. Hull.—The Physical Geology of Sinai and Palestine.

J. F. Blake.—On two tunnel-sections in the Cambrian of Carnarvonshire.

Dr. H. J. Johnston-Lavis.—Report of the Committee on the Volcanic Phenomena of Vesuvius.

Rev. E. Jones.—Report of the Committee on the Elbolton Cave.

B. Harrison.—Report of the Committee on the Excavations at Oldbury Hill.

Prof. T. G. Bonney.—On the Relation of the Bunter Pebbles of the English Midlands to those in the Old Red Sandstone conglomerates of Scotland.

A. Harker.—On Porphyritic Quartz in Basic Igneous Rocks.

Alexander Somervail.—On the Relations of the Rocks of the Lizard district.

B. N. Peach and *J. Horne.*—On the Ice-shed in the North-West Highlands during the Maximum Glaciation.

B. N. Peach and *J. Horne.*—On a Bone Cave in the Limestone of Assynt.

Prof. W. J. Sollas.—Report on the Committee on Investigating the Structure of a Coral Reef.

Miss M. Ogilvie.—Landslips in the St. Cassian Strata of the South Tyrol.

J. G. Goodchild.—On a Granite junction in Mull.

J. G. Goodchild.—The St. Bees' Sandstone and its associated Rocks.

J. J. H. Teall.—The Sequence of Gneissose Rocks.

Prof. W. J. Sollas.—Supposed Radiolarian Remains from the Slates of Howth.

Prof. J. W. Sollas.—Supposed Radiolarian Remains from the Culdaff Limestone.

E. T. Newton.—On Some Dicynodont and other Reptilian remains from the Elgin Sandstone.

Dr. R. H. Traquair.—On the Distribution of Fossil Fishes in the Edinburgh District.

M. Laurie.—The Eurypterid Fauna of the Silurian Rocks.
Prof. T. R. Jones.—Report of the Committee on Fossil Phyllopoda.
R. B. Newton.—On the occurrence of *Chonetes Pratti* (Davidson) in the Carboniferous Rocks of Western Australia.
A. Smith Woodward.—Report of the Committee on the Registration of Type Specimens.
G. R. Vine.—Report of the Committee on the Cretaceous Polyzoa.
C. Davison.—Report of the Committee on Earth Tremors.
A. Harker.—On Porphyritic Quartz in Basic Igneous Rocks.
Dr. H. J. Johnston-Lavis.—The Occurrence of Pisolitic Tuff in the Pentlands.
W. W. Watts.—Notes on some Limerick Traps.

TITLES OF PAPERS BEARING UPON GEOLOGY READ IN OTHER SECTIONS:—

Section A.—Mathematical and Physical Science.

Report of the Committee on Meteoric Dust.
Report of the Committee on the Seismological Phenomena of Japan.
Report of the Committee on Underground Temperature.

Section D.—Biology.

H. O. Forbes.—Remarks on a Series of Extinct Birds of New Zealand, recently discovered.
W. Carruthers, F.R.S.—On the structure of the stem of a typical *Sigillaria.*
T. Hick.—On *Calamostachys Binneyana.*
A. C. Seward. —Notes on specimens of *Myeloxylon* from the Millstone Grit and Coal-measures.

Section H.—Anthropology.

H. O. Forbes.—On the Contemporaneity of Man and the Moa.
Report of the Prehistoric Inhabitants Committee.

II.—BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, EDINBURGH, 1892.

Address to the Geological Section by PROFESSOR C. LAPWORTH, LL.D., F.R.S., F.G.S., President of the Section.

IT has, I believe, been the rule for the man who has been honoured by election to the Chair of President of this Geological Section of the British Association to address its members upon the recent advances made in that branch of geology in which he has himself been most immediately interested. It is not my intention upon the present occasion to depart from this time-honoured custom ; for it has both the merit of simplicity and the advantage of utility to recommend it. In this way each branch of our science, as it becomes in turn represented, not only submits to the workers in other departments a report of its own progress, but presents by implication a broad sketch of the entire geological landscape, seen through the coloured glasses, it may be, of divisional prejudice, but at any rate instructive and corrective to the workers in other departments, as being taken from what is to them a novel and an unfamiliar point of view.

Now every tyro in geology is well aware of the fact that the very backbone of geological science is constituted by what is known as stratigraphical geology, or the study of the geological formations. These formations, stratified and unstratified, build up all that part of the visible earth-crust which is accessible to

the investigator. Their outcropping edges constitute the solid framework, the surface of which forms the physical geography of the lands of the present day, and their internal characters and inter-relationships afford us our only clues to the physical geographies of bygone ages. Within them lies enshrined all that we may ever hope to discover of the history and the development of the habitable world of the past.

These formations are to the stratigraphical geologist what species are to the biologist, or what the heavenly bodies are to the astronomer. It was the discovery of these formations which first elevated geology to the rank of a science. In the working out of their characters, their relationships, their development, and their origin, geology finds its means, its aims, and its justification. Whatever fresh material our science may yield to man's full conception of nature, organic and inorganic, must of necessity be grouped around these special and peculiar objects of its contemplation.

When the great Werner first taught that our earth-crust was made up of superimposed rock-sheets or formations arranged in determinable order, the value of his conclusions from an economic point of view soon led to their enthusiastic and careful study; but his crude theory of their successive precipitation from a universal chaotic ocean disarmed the suspicions of the many until the facts themselves had gained such a wide acceptance that denial was no longer possible. But when the greater Scotchman, Hutton, asserted that each of these rock-formations was in reality nothing more nor less than the recemented ruins of an earlier world, the prejudices of mankind at large were loosed at a single stroke. Like Galileo's assertion of the movement of the globe, this demanded such an apparently undignified and improbable mode of creation that there is no wonder that, even down to the present day, there still exist some to whom this is a hard saying, to be taken, if taken at all, in homœopathic doses and with undisguised reluctance.

Hutton as regards his philosophy was, as we know, far in advance of his time. With all the boldness of conviction he unflinchingly followed out these ideas to their legitimate results. He claimed that as the stratified formations were composed of similar materials—sands, clays, limestones, and muds—to those now being laid down in the seas around our present coasts, they must, like them, have been the products of ordinary natural agencies of rain, rivers, and sea waters, internal heat and external cold, acting precisely as they act now. And, further, as these formations lie one below the other, in apparently endless downward succession, and all formed more or less of these fragmentary materials, so the present order of natural phenomena must have existed for untold ages. Indeed, to the commencement of this order he frankly admits 'I see no trace of a beginning or sign of an end.'

The history of the slow acceptance of Hutton's doctrines, even among geologists, is, of course, perfectly familiar to us all. William Smith reduced the disputed formations to order, and showed that not only was each composed of the ruins of a vanished land, but that each contained in its fossils the proof that it was deposited in a vanished sea inhabited by a special life creation. Cuvier followed, and placed it beyond question that the fossilised relics of these departed beings were such as made it absolutely unquestionable that these creatures might well have inhabited the earth at the present day. Lyell completed the cycle by demonstrating stage by stage the efficiency of present natural agencies to do all the work required for the degradation and rebuilding of the formations. Since his day the students of stratigraphical geology have universally acknowledged that in the study of present geographical causes lies the key to the geological formations and the inorganic world of the past.

In this way the road was paved for Darwin and the doctrine of descent. The aid which had been so ungrudgingly afforded by biology to geology was repaid by one of the noblest presents ever made by one science to another. For the purposes of geology, the science of biology had practically completed a double demonstration: first, that the extinct life discernible in the geological formations was linked inseparably with the organic life of the present; and, second, that every fossil recognised by the geologist was the relic of a creature that might well have existed upon the surface of the earth at the present time. Geology repaid its obligation to biology by the still greater twofold demonstration: first, that in the

economy of nature the most insignificant causes are competent to the grandest effects, if only a sufficiency of time be granted them; and, second, that in the geological formations we have the evidences of the actual existence of those mighty eons in which such work might be done.

The doctrine of organic evolution would always have remained a metaphysical dream had geology not given the time in which the evolution could be accomplished. The ability of present causes to bring about slow and cumulative changes in the species is, to all intents and purposes, a biological application of Hutton's ideas with respect to the original geological formations. Darwin was a biological evolutionist, because he was first a uniformitarian geologist. Biology is pre-eminent to-day among the natural sciences, because its younger sister, Geology, gave it the means.

But the inevitable consequence of the work of Darwin and his colleagues was that the centre of gravity, so to speak, of popular regard and public controversy was suddenly shifted from stratigraphical geology to biology. Since that day stratigraphical geology, to its great comfort and advantage, has gone quietly on its way unchallenged, and all its more recent results have, at least by the majority of the wonder-loving public, been practically ignored.

Indeed, to the outside observer it would seem as if stratigraphical geology for the last thirty years had been practically at a standstill. The startling discoveries and speculations of the brilliant stratigraphists of the end of the last century and first half of the present forced the geology of their day into the very front rank of the natural sciences, and made it perhaps the most conspicuous of them, all in the eyes of the world at large. Since that time, however, their successors have been mainly occupied in completing the work of the great pioneers. The stratigraphical geologists themselves have been almost wholly occupied in laying down upon our maps the superficial outlines of the great formations, and working out their inter-relationships and subdivisions. At the present day the young stratigraphical student soon learns that all the limits of our great formations have been laid down with accuracy and clearness, and finds but little to add to the accepted nomenclature of the time.

Our palæontologists also have equally busied themselves in working out the rich store of the organic remains of the geological formations, and the youthful investigator soon discovers that almost every fossil he is able to detect in the field has already been named, figured, and described, and its place in the geological record more or less accurately fixed.

In France, in Germany, in Norway, Sweden, and elsewhere, in Canada and in the United States, work as thorough and as satisfactory has been accomplished, and the local development of the great stratified formations and their fossils laid down with detail and clearness.

Many a young unfledged but aspiring geologist alive to these facts, and contrasting the well-mapped ground of the present time with the virgin lands of the days of the great pioneers, finds it hard to stifle a feeling of keen regret that there are nowadays no new geological worlds to conquer, no new systems to discover and name, and no strange and unexpected faunas to unearth and bring forth to the astonished light of day. The youth of stratigraphical geology, with all its wonder and freshness, seems to have departed, and all that remains is to accept, to commemorate, and to round off the glorious victories of the dead heroes of our science.

But to the patient stratigraphical veteran, who has kept his eyes open to discoveries new and old, this lull in the war of geological controversy presents itself rather as a grateful breathing time; the more grateful as he sees looming rapidly up in front the vague outlines of those oncoming problems which it will be the duty and the joy of the rising race of young geologists to grapple with and to conquer as their fathers met and vanquished the problems of the past. He knows perfectly well that Geology is yet in her merest youth, and that to justify even her very existence there can be no rest until the whole earth-crust and all its phenomena, past, present, and to come, have been subjected to the domain of human thought and comprehension. There can be no more finality in Geology than in any other science; the discovery of to-day is merely the stepping-stone to the discovery of to-morrow; the living theory of to-morrow is nourished by the relics of its parent theory of to-day.

Now if we ask what are these formations which constitute the objects of study of the stratigraphical geologist, I am afraid that, as in the case of the species of the biologist, no two authorities would agree in framing precisely the same definition. The original use of the term formation was of necessity lithological, and even now the name is most naturally applied to any great sheet of rock which forms a component member of the earth-crust; whether the term be used specifically for a thin homogeneous sheet of rock like the Stonesfield slate, ranging over a few square miles; or generically for a compound sheet of rock, like the Old Red Sandstone, many thousands of feet in thickness, but whose collective lithological characteristics give it an individuality recognizable over the breadth of an entire continent.

When Werner originally discovered that the 'formations' of Saxony followed each other in a certain recognizable order, a second characteristic of a formation became superposed upon the original lithological conception—namely, that of determinate 'relative position.' And when William Smith proved that each of the formations of the English Midlands was distinguished by an assemblage of organic remains peculiar to itself, there became added yet a third criterion —that of the possession of 'characteristic fossils.'

But these later superposed conceptions of time—succession and life-type—are far better expressed by dividing the geological formations into zoological *zones*, on the one hand, and grouping them together, on the other hand, into chronological *systems*. For in the experience of every geologist he finds his mind instinctively harking back to the bare lithological application of the word 'formation,' and I do not see that any real advantage is gained by departing from the primitive use of the term.

A 'zone,' which may be regarded as the *unit* of *zoological succession*, is marked by the presence of a special fossil, and may include one or many subordinate formations. A *system*, which is, broadly speaking, the *unit of geological time* or *succession*, includes many 'zones,' and often, but not always, many 'formations.' A *formation*, which is the *unit of geological stratigraphy*, is a rock sheet composed of many strata possessing common lithological characters. The formation may be simple, like the chalk, or compound, like the New Red Sandstone, but, simple or compound, local or regional, it must be always recognizable, geographically and geologically, as a lithological individual.

As regards the natural grouping of these lithological individuals as such, fair progress has been made of late years, and our information is growing apace. We know that there are at any rate three main groups: 1st. The stratified formations due to the action of moving water above the earth-crust. 2nd. The igneous formations which are derived from below the earth-crust. 3rd. The metamorphic formations which have undergone change within the earth-crust itself. We know also that of these three the only group which has hitherto proved itself available for the purpose of reading the past history of the globe is that of the stratified formations.

Studying these stratified formations therefore in greater detail, we find that they fall naturally in their turn into two sets, viz.: a mechanical set of pebble beds, sandstones and clays formed of rock fragments washed off the land into the waters, and an organic set of limestones, chalk, etc., formed of the shells and exuviæ of marine organisms.

But when we attempt a further division of these two sets our classification soon begins to lose its definiteness. We infer that some formations, such as the Old Red and the Triassic, were the comparatively rapid deposits of lakes and inland seas; that others, like the Coal-measures, London-clay, etc., were the less rapid deposits of lagoons, river valleys, deltas, and the like; that others, like our finely laminated shales and clays of the Silurian and Jurassic, were the slower deposits of the broader seas; and finally, that others, like our Chalk and Greensand, were possibly the extremely slow deposits of the oceanic deeps.

Nevertheless, after looking at the formations collectively, there remains no doubt whatever in the mind of the geologist that their mechanical members are the results of the aqueous degradation of vanished lands, and that their organic members are the accumulated relics of the stony secretions of what once were living beings. Neither is there any possibility of escape from the conclusion that they have all been deposited by water in the superficial hollows of the sea-bottoms and ocean floors of the earth-crust of their time.

In the life of every individual stratified formation of the mechanical type we

can always distinguish three stages: first, the stage of erosion and transportation, in which the rock fragments were worn off the rocks of the higher ground and washed down by rain and rivers to the sea; second, a stage of deposition and consolidation below the surface of the quiet waters; and third, a final stage in which the completed rock-formation was bent and upheaved, in part at least, into solid land. In the formations of the organic type three corresponding stages are equally discernable: first, the period of mineral secretion by organized beings; second, the period of deposition and consolidation; and third, the final period of local elevation in mass. But one and all, mechanical and organic alike, they bear in their composition, in their arrangement, and in their fossils, abundant and irresistible evidence that they *were* the products and that now they are the memorials of the physical geography of their time.

Guided by the principles of Hutton and Lyell, geologists have worked out with great care and completeness the effects of those agencies which rule in the first of these three life-stages in the history of a mechanical formation. No present geological processes are more familiar to the young geologist than those of denudation, erosion, and transportation. They form together the subject-matter of that most wonderful fascinating chapter in geology which from its modest opening among the quiet Norfolk Sandhills sweeps upwards and onwards without a break to its magnificent close on the brink of the gorge of the Colorado. But our knowledge of the detailed processes of deposition and consolidation which rule in the second stage is still exceedingly imperfect, although a flood of light has been thrown upon the subject by the brilliant results of the *Challenger* Expedition. And we are compelled to admit that our knowledge of the operations of those agencies which rule in the processes of upheaval and depression is as yet almost nil; and what little we have already learnt of the effects of these agencies is the prey of hosts of conflicting theories that merely serve to annoy and bewilder the working student of the science.

But not one of the formative triad of detrition, deposition, and re-elevation can exist without the others. No detrition is possible without the previous upheaval of the rock-sheet, from which material can be removed; no deposition is possible without the previous depression of the rock-sheet, which forms the basin in which the fragmentary material can be laid down.

Our knowledge, therefore, of the origin and meaning of any geological formation whatever can at most be only fragmentary until this third chapter in the life-history of the geological formation has been attacked in earnest.

Now all the rich store of knowledge we possess respecting the first stage in the life of a geological formation has been derived from a comparison of certain phenomena which the stratigraphical geologist finds in the rock formations of the past, with correspondent phenomena which the physical geographer discovers on the surface of the earth at the present. And all that we know of the second stage again has been obtained in precisely the same way. Surely analogy and common sense both teach us that all which is likely to be of permanent value to us as regards the final stage of elevation and depression must be sought for in the same direction.

Within the last twenty years or so many interesting and vital discoveries have been made in the stratigraphy of the rock formations, which bear largely upon this obscure chapter of elevation and depression. And I propose on this occasion that we try to summarise a few of these new facts, and then, reading them in conjunction with what we actually know of the physical geography of the present day, try to ascertain how such mutual agreement as we can discover may serve to aid the stratigraphical geologist in his interpretation of the true meaning of the geological formations themselves. We may not hope for many years to come to read the whole of this geological chapter, but we may perhaps modestly essay an interpretation of one or two of the opening verses.

In the physical geography of the present day we find the exterior of our terraqueous globe divided between the two elements land and water. We know that the solid geological formations exist everywhere beneath the visible surface of the lands, but of their existence under the present ocean floor we have as yet no absolute certainty. We know both the form of the surface and the composition of the surface of the continental parts of the lithosphere; we only know as yet even in outline the form of its oceanic portions. The surface of each of our great

continental masses of land resembles that of a long and broad arch-like form, of which we see the simplest type in the New World. The surface of this American arch is sagged downwards in the middle into a central depression which lies between two long marginal plateaux, and these plateaux are finally crowned by the wrinkled crests which form our modern mountain systems. The surface of each of our ocean floors exactly resembles that of a continent turned upside down. Taking the Atlantic as our simplest type, we may say that the surface of each ocean basin resembles that of a mighty trough or syncline, buckled up more or less centrally into a medial ridge, which is bounded by two long and deep marginal hollows, in the cores of which still deeper grooves sink to the profoundest depths. This complementary relationship descends even to the minor features of the two.

Where the great continental sag sinks below the ocean level we have our gulfs and our Mediterranean, seen in our type continent as the Mexican Gulf and Hudson Bay. Where the central oceanic buckle attains the water-line we have our oceanic islands, seen in our type ocean as St. Helena and the Azores. Although these apparent crust-waves are neither equal in size nor symmetrical in form, this complementary relationship between them is always discernible. The broad Pacific depression seems to answer to the broad elevation of the Old World —the narrow trough of the Atlantic to the narrow continent of America.

Every primary wave of the earth's surface is broken up into minor waves, in each of which the ridge and its complementary trough are always recognisable. The compound ridge of the Alps answers to the compound Mediterranean trough; the continuous western mountain chain of the Americas to the continuous hollow of the Eastern Pacific which bounds them; the sweep of the crest of the Himalaya to the curve of the Indo-Gangetic depression. Even where the surface waves of the lithosphere lie more or less buried beneath the waters of the ocean and the seas, the same rule always obtains. The island chains of the Antilles answer to the several Caribbean abysses, those of the Ægean Archipelago answer to the Levantine deeps.

Draw a section of the surface of the lithosphere along a great circle in any direction, the rule remains the same: crest and trough, height and hollow, succeed each other in endless sequence, of every gradation of size, of every degree of complexity. Sometimes the ridges are continental, like those of the Americas; sometimes orographic, like those of the Himalaya; sometimes they are local, like those of the English Weald. But so long as we do not descend to minor details we find that every line drawn across the earth's surface at the present day rises and falls like the imaginary line drawn across the surface of the waves of the ocean. No rise of that line occurs without its complementary depression; the two always go together, and must of necessity be considered together. Each pair constitutes one of those geographical units of form of which every continuous direct line carried over the surface of the lithosphere of our globe is made up. This unit is always made up of an arch-like rise and a trough-like depression which shade into each other along a middle line of contrary curvature. It resembles the letter S, or Hogarth's line of beauty, and is clearly identical in form with the typical wave of the physicist. Here, then, we reach a very simple and natural conclusion, viz., the surface of the earth-crust of the present day resembles that of a series of crust-waves of different lengths and different amplitudes, more or less irregular and complex, it is true, but everywhere alternately rising and falling in symmetrical pairs like the waves of the sea.

Now this rolling wave-like earth-surface is formed of the outcropping edges of the rock formations which are the special objects of study of the stratigraphical geologist. If, therefore, the physiognomy of the face of our globe is any real index of the character of the personality of the earth-crust beneath it, these collective geographical features should be precisely those which answer to the collective structural characters of the geological formations.

In the earlier days of geology one of the first points recognised by our stratigraphists was the fact that the formations were successive lithological sheets, whose truncated outcropping edges formed the present surface of the land, and that these sheets lay inclined at an angle one over the other, as William Smith quaintly expressed it, like a tilted 'pile of slices of bread and butter.' But as discovery progressed the explanation of the arrangement soon became evident. The formations revealed themselves as a series of what had originally been deposited as

horizontal sheets, lying in regular order one over the other, but which had been subsequently bent up into alternating arches and troughs (i.e. the anticlines and synclines of the geologist), while their visible parts, which now constitute the surface of our habitable lands, were simply those parts of the formation which are cut at present by the irregular plane of the present earth's surface. All those parts of the great arches and troughs formerly occurring above that plane have been removed by denudation; all those parts below that plane lie buried still out of sight within the solid earth-crust, although in every geological section of sufficient extent it was seen that the anticline or arch never occurred without the syncline or trough—in other words, that there was never a rise without a corresponding fall of the stratum. Yet it is only of late years that the stratigraphical geologist has come clearly to recognize the fact that the anticline and syncline must be considered together, and must be united as a single crust-wave, for the arch is never present without its complementary trough, and the two together constitute the tectonic or orographic unit. *The Fold*, the study of which, so brilliantly inaugurated by Heim in his 'Mechanismus der Gebirgsbildung,' is destined, I believe, in time, to give us the clue to the laws which rule in the local elevation and depression of the earth-crust, and furnish us with the means of discovery of the occult causes which lie at the source of those superficial irregularities which give to the face of our globe its variety, its beauty, and its habitability.

We have said already that this wave or fold of the geologist resembles that of the wave of the physicist.

Now we may regard such a wave as formed of two parts, the arch-like part above and the trough-like part below. The length of the wave is naturally the length of that line joining the outer extremities of the arch and trough, and passing through the centre node or point of origin of the wave itself, which bisects the line of contrary curvatures. The amplitude of the wave is the height of the arch added to the depth of the trough. Now the arch part of such a wave, if perfectly symmetrical, may clearly be regarded as belonging either to a wave travelling to the right, in which case the complementary trough is the one in that direction, or it may be regarded as belonging to a wave travelling to the left, in which case its trough must be the one in that direction. But as in the case of the sea wave, the advancing slope of the wave is always the steeper, and the real centre of the wave must lie half-way down this steeper slope; so there is no difficulty in recognizing the centre of a geological fold and its real direction of movement.

The fold of the geologist differs from the ordinary wave of the physicist, essentially in the fact that even in its most elementary conception, as that of a plate bent by a pressure applied from opposite sides, it necessarily includes the element of thickness. And this being the case, the rock sheet which is being folded and curved has different layers of its thickness affected differently; in the arch of the fold the upper layers of the rock sheet are extended, while its lower layers are compressed. On the contrary, in the trough of the fold the upper layers are compressed and the lower layers are extended. But in both arch and trough alike there exists a central layer, which, beyond taking up the common wave-like form, remains practically unaffected.

But the geological fold has in addition to length and thickness the further element of breadth, and this fact greatly complicates the phenomena.

But many of the movements which take place in a rock sheet which is being folded, or in other words those produced by the bending of a compound sheet composed of many leaves, can be fairly well studied in a very simple experiment. Take an ordinary large note-book, say an inch in thickness, with flexible covers, rule carefully a series of parallel lines across the edges of the leaves at the top of the book, about ½ of an inch apart, and exactly at right angles to the plane of the cover. Then, holding the front edges loosely, press the book slowly from back and front into an S-like form until it can be pressed no further. As the wave grows it will be noticed that the cross lines which have been drawn on the upper edge of the book remain fairly parallel throughout the whole of the folding process, except in the central third of the book, where they arrange themselves into a beautiful sheaf-like form, showing how much the leaves of the book have sheared or slidden over each other in this central portion. It will also be seen when the S is complete that the book has been forced into a third of its former

breadth. It is clear that the wave the book now forms must be regarded as made up of three sections: viz. a section forming the outside of the trough on the one side, and a section forming the outside of the arch on the other, and a central or common section, which may be regarded either as uniting or dividing the other two.

As this experiment gives us a fair representation of what takes place in a geological fold, we see at a glance that the geologist is forced to divide his fold into three parts—an arch limb, a trough limb, and a middle limb—which latter we may call the *copula* or the *septum*, according as we regard it as connecting or dividing the other two. Our note-book experiment, therefore, shows us also that in the trough limb and the arch limb the leaves or layers undergo scarcely any change of relative position beyond taking on the growing curvature of the wave. But the layers in the central part, or *septum*, undergo sliding and shearing. It will be found also, by gripping the unbound parts of the book firmly and practicing the folding in different ways, that this *septum* is also a region of warping and twisting. This simple experiment should be practised again and again until these points are apparent, and the various stages of the folding process become clear; the surface of the book being forced first into a gentle arch-like rise with a corresponding trough-like fall, then stage by stage the arch should be pushed over on to the trough until the surfaces of the two are in contact and the book can be folded no further.

(*To be continued.*)

REVIEWS.

I.—Argiles de Speeton et leurs Équivalents. By A. Pavlow and G. W. Lamplugh. Extracted from the "Bulletin de la Société Impér. des Naturalistes de Moscou," Nos. 3 and 4, 1891. With eleven plates (Moscow, 1892).

THAT the study of life-zones furnishes the key to the elucidation of the relationship of fossiliferous rocks, however widely separated geographically, has long been recognised by palæontologists, and this lesson is enforced anew in the admirable monograph before us.

The authors divide their work into three parts; the first (pp. 1–33) contains a description of the beds at Speeton (Speeton Clay) and their equivalents in Lincolnshire, by Mr. Lamplugh; the second (pp. 34–155) gives a description, written by M. Pavlow, of those forms of Mesozoic Cephalopods — Belemnites and Ammonites— which are of the greatest importance for purposes of comparative stratigraphy. These fossils are compared with the fossils of other countries, chiefly with Russian forms, of which some are figured as well as described. This part of the work is preceded by a table (pp. 36–37) indicating the sub-divisions of the Jurassic and Lower Cretaceous beds of the neighbourhood of Moscow, and of the lower Volga region (Bas Wolga). Furthermore, M. Pavlow deals with the relationship between the Speeton and Lincolnshire beds and those of other countries (pp. 156–201).

The material upon which the memoir under review was based consisted in the main of Mr. Lamplugh's collection of fossils made at Speeton and in Lincolnshire, supplemented by many specimens lent to the authors by the officials connected with some of the leading Continental and British Museums.

In order to make clear the remarks which follow we here reproduce part of a stratigraphical table furnished by M. Pavlow, showing the different "zones" into which the Speeton and Russian beds have been divided.

Lincolnshire.	Speeton.	Government of Simbirsk.	Government of Moscow.
Tealby Limestone.	B. Zone of *Hoplites Deshayesi* and *Belemnites brunvicensis*.	Zone of *Hoplites Deshayesi* and *Amaltheus bicurvatus*.	Unfossiliferous sands.
Tealby Clay.	C. 1—C. 6. Zone of *Olcostephanus Decheni* and *O. speetonensis*.	Zone of *Olcostephanus Decheni* and *O. discofalcatus*.	Sandstone of Worobiewo with *Olcostephanus Decheni* and *O. discofalcatus*.
	C. 6—C. 7. Zone of *Olcostephanus subinversus* and *Belemnites jaculum*.	Zone of *Olcostephanus versicolor*.	
Upper part of the ferruginous rock of Claxby, with *Hoplites regalis* and *Belemnites jaculum*.	C. 8—C. 11. Zone of *Hoplites regalis*, *Astieria Astieri* (type), *Belemnites jaculum*.	Wanting, or is represented by sands poor in fossils (*Belemnites subquadratus*).	Zone represented perhaps by orange sands with black phosphatic nodules (with *Hoplites rjasanensis*).
Lower part of the ferruginous rock of Claxby, with *Olcostephanus Blakei*, *Belemnites russiensis*, etc.	D. 1—D. 3. Zone of *Olcostephanus gravesiformis*, *O. Keyserlingi*, *Belemnites lateralis*, etc.	Zone of *Olcostephanus gravesiformis*, *O. Keyserlingi*, *Belemnites lateralis*, etc.	Sands almost without fossils (with remains of plants).
Spilsby Sandstone with *Olcostephanus subditus*.	D. 4—D. 8. Zone of *Olcostephanus fragilis*, cf. *O. subditus*, etc.	Zones of *Olcostephanus Kaschpuricus*, and *O. subditus*.	Zones of *Olcostephanus nodiger* and *O. subditus*.
Schists with *Discina latissima* and crushed Ammonites.	"Coprolite bed." E.	Zone with *Ammonites giganteus*. Zone with *Virgatites virgatus*.	Zone with *Ammonites triplicatus* and *A. Blakei*. Zone with *Virgatites virgatus*.
	Beds F. with *Belemnites magnificus*, *B. porrectus*, and crushed Ammonites.	Beds with *Belemnites magnificus* and the first representatives of the Virgati (not yet completely studied).	
Kimmeridgian slates.	Beds with *Hoplites pseudomutabilis*.	Beds with *Hoplites pseudomutabilis*.	

These may be taken in descending order, attention being directed chiefly to the lower Volga region, of which the series of beds is the most complete. Below the Gault in this region there are clays containing concretions of marly limestone, and characterized by *Hoplites Deshayesi, Amaltheus bicurvatus*, and by large forms of *Ancyloceras*, which are found both in concretions and in the clay itself. The presence of Gault cephalopods clearly indicates the horizon to which these clays belong. The Gault clays rest upon a thick series of more or less marly and gypsiferous clays, of which the upper part is poor in fossils, making it difficult to establish the lower boundaries of the Gault. But a little lower down two horizons are apparent, characterized by different Ammonites; the upper one with *Olcostephanus* (*Simbirskites*) *Decheni, S. discofalcatus, S. progrediens, S. umbonatus, S. speetonensis* (*fasciato-falcatus*, Lah.), *S. Barboti, Belemnites Jasikowi, B. brunsvicensis, B. absolutiformis*, the lower, which is thinner, containing *Simbirskites versicolor, S. inversus, Belemnites Jasikowi, B. absolutiformis*. Comparing this part of the Simbirsk section with that of Speeton (see Table) the striking resemblance between the two faunas is apparent, as also the similarity in the order of their succession. The number of forms common to both leaves no room to doubt that in the Simbirsk horizon we have the exact representative of the zones of *Olcostephanus* (*Simbirskites*) *speetonensis*, and *S. subinversus* of Speeton. There are, it is true, some dissimilarites between the beds of the two countries, but these are unimportant, and fresh researches might completely negative them. The zone of *S. Decheni* and *S. discofalcatus* is developed also in the neighbourhood of Moscow (Grés de Worobiewo) and contains *Crioceras Matheroni*. On descending lower in the series, however, the striking resemblance between the Russian and Speeton beds is no longer discernible. For, while at Speeton the succeeding zone (c. 8 to c. 11) is characterized by *Hoplites regalis, Holcodiscus rotula, Astieria Astieri, Hoplites Roubaudi, Belemnites jaculum* (representing the upper part of the "Claxby Ironstone" of Lincolnshire), this zone is entirely wanting in the Simbirsk[1] region. Its absence is the more remarkable since the following zone, which forms the base of the *Hoplites regalis* beds of Speeton, is common to both countries, although in Russia it is only developed in certain places. The zone in question (D. 1 to D. 3) is met with in the neighbourhood of Syzran (village of Kachpour), and its stratigraphical position is found to be above that of the upper zone of the first stage of Rouillier (=Volgien supérieur). It here contains *Olcostephanus* (*Polyptychites*) *Keyserlingi, P. ramulicosta, P. gravesiformis, Belemnites lateralis, B. subquadratus*, and many other forms. No trace of this interesting fauna has been met with in the environs of Moscow. Remains of plants in arenaceous beds, of Wealden or Purbeck age, are found here, and these beds rest upon the upper stage of Rouillier, which near Syzran forms the

[1] Simbirsk is a province situated in the western part of East Russia, nearly due west of Moscow.

base of the "Petchorian" stage[1] The Rouillier stage is very rich in fossils and its fauna has been carefully worked up. It is divided into two zones, the upper of which contains *Olcostephanus* (*Craspedites*) *nodiger*, *C. kaschpuricus*, and *Oxynoticeras subclypeiforme*, and the lower contains *Olcostephanus* (*Craspedites*) *subditus*, *C. fragilis*, and *Oxynoticeras catenulatum*. *Belemnites lateralis*, *B. russiensis* and *B. mosquensis* are found in both zones; *Belemnites subquadratus* is also met with, though rarely.

Turning again to Speeton we find that the beds there (D. 4 to D. 8) corresponding with the upper stage of Rouillier are those situated immediately below D. 1 to D. 3, and that they contain the following Cephalopods, viz., *Belemnites lateralis*, *B. russiensis*, *B. subquadratus*, *B. explanatoides*, *Olcostephanus* (*Craspedites*) *fragilis*, *C. subditus*, and *Oxynoticeras*, cf. *catenulatum*. Excluding the two last-named Ammonites, which were found to be too young for decisive identification, the list may be completed by the Cephalopods of Lincolnshire of corresponding horizon (Spilsby Sandstone). This supplies an undoubted *Craspedites subditus*, so that there remains only *Oxynoticeras catenulatum* upon which any doubt might be thrown. But even if the last-named species did not exist at Speeton, the number of forms common to the Russian and English horizons in question would be sufficient to prove the relationship between them.

We now reach the beds forming the base of the *Craspedites subditus* and *C. fragilis* beds, which in Russia are rich in Ammonites of the Virgati group. Two zones have been observed up to the present time, viz., the zone of *Virgatites virgatus*, and *V. Pallasi*, and that of *V. triplicatus* and *V. Blakei*. Representing these zones at Speeton there are (1) the "Coprolite bed," (2) the bituminous schists containing crushed Ammonites, and *Belemnites magnificus*, *B. porrectus*, and *B. obeliscoides*, which are observed at Speeton, below the *Belemnites lateralis* beds. The Ammonites found in the "Coprolite bed" are too fragmentary to be identified with exactness; but the following species were approximately determined, viz., *Virgatites*, cf. *V. Panderi*, *Virgatites*, cf. *V. Tchernyschovi*, *Virgatites*, cf. *V. scythicus*, *Virgatitus*, cf. *V. dorsoplanus*, *Virgatites*, cf. *V. miatschkoviensis*, *Perisphinctes lacertosus*. Going down still lower in the stratigraphical series undoubted Kimmeridgian beds are met with containing *Hoplites eudoxus*, *H. pseudomutabilis*, and *H. subundaræ*. The beds are the same as those which constitute the base of the Virgati beds in Russia. Thus, even putting aside palæontological evidence, the stratigraphy alone would suffice to prove that the "Coprolite bed" E, and the bituminous schists forming its base correspond to the Virgati beds of the Russian Jurassic. The palæontological evidence, however, is not so convincing, owing to the bad state of preservation of the Speeton fossils, and an imperfect knowledge of the lowest zone of the Virgati beds. Notwithstanding

[1] This sub-division has been so designated by M. Pavlow. It is a well developed horizon, characterized by a special fauna. It was first discovered by Keyserling, who described it in his "Wissenschaftliche Beobachtungen auf einer Reise in das Petschora Land, 1846."

this, the regular succession of zones in Russia and England, holding a similar fauna, justifies the anticipation that the parallelism between the Upper Jurassic and Necomian beds of Russia, and those of Western Europe, may yet be established upon the firm basis of palæontological facts.

In his chapter on the comparative stratigraphy of the Speeton Clay (pp. 156–201), M. Pavlow cites the opinions of Toucas, Oppel, Blake, C. Struckmann, Nikitin, Tchernychew, and others, on the question of the age of the Portlandian and Tithonic. While not discussing the point as to whether these formations belong to the Cretaceous or to the Jurassic, M. Pavlow observes that the history of the development of the faunas, so far as they are known, is distinctly opposed to the division of the Tithonic and the Portlandian between the two systems.

The following new species of Belemnites are described by M. Pavlow, viz., *Belemnites obeliscoides, B. explanatoides, B. Rouillieri, B. mosquensis, B. breviaxis, B. cristatus, B. obtusirostris, B. speetonensis.* A chapter upon the classification of Belemnites (pp. 89–96) follows the description of the species, the divisions adopted being based upon those of Neumayr, viz., (1) *Notocœli,* (2) *Bipartiti,* (3) *Dilatati,* (4) *Suprasulcati* (=*Canaliculati,* Neumayr, non Zittel), (5) *Acuarii,* (6) *Infradepressi.* Of Ammonites the following new subgenera and species are described, viz., *Virgatites* (=Ammonites of the group *Virgati,* auct.); *Craspedites* (=Olcostephani of the group *O. subditus*); *Polyptychites* (=Olcostephani of the group *O. polyptychus*), *Olcostephanus* (*Polyptychites*) *triplodiptychus, O.* (*P.*) *ramulicosta, O.* (*P.*) *Beani, O.* (*P.*) *gravesiformis, O.* (*P.*) *Lamplughi; Astieria* (=Olcostephani of the group *O. Astieri*), *Olcostephanus* (*Astieria*) *sulcosus*; *Simbirskites* (=Olcostephani of the group *O. Decheni*); *Acanthoceras* (?) *peltoceroides.*

ARTHUR H. FOORD.

II.—THE VOLCANIC ROCKS OF COLOMBIA.

W. REISS AND A. STÜBEL: REISEN IN SÜD-AMERIKA. GEOLOGISCHE STUDIEN IN DER REPUBLIK COLOMBIA. Part I. Petrographie. 1. Die Vulkanischen Gesteine. By RICHARD KÜCH. (Berlin, 1892. 4to. xiv.+204 pp. Nine Plates.

DURING the past ten years many important additions have been made to the knowledge of the volcanic rocks of the northern Andes, including contributions by Karsten, Bonney, Siemiradzki, Hettner, and Linck; a far more elaborate work has now been published giving the results of Dr. Küch's searching investigation of the large collection brought home by Drs. Reiss and Stübel from the expedition rendered famous by the important anthropological discoveries that attended their excavations at Ancon. The specimens of volcanic rocks alone number 1500, which are now preserved at the Museums of Berlin and Dresden, or in the collection of Dr. Reiss; some of them have been previously described, as the memoir of Carl Höpfner, issued in 1881, was based upon part of the material.

Dr. Reiss prefaces the work by a short introduction describing the main features in the relations of the Colombian Andes; at the northern end of the country these form three distinct ranges, known as the eastern, central, and western Cordilleras. They are separated by the Magdalena and Cauca valley; to the south these contract till finally the eastern range merges into the central chain. The two lateral Cordilleras are composed of Cretaceous and Jurassic sedimentary rocks, but the central chain is formed of old crystalline schists, gneisses, and Cretaceous eruptives. The difficulty in the study of the relations of these is increased by the fact that the highest peaks are glacier clad.

Dr. Küch's description of the rocks is divided into two parts, a general and a special. In the former the rocks are classified petrographically, and in the latter topographically; in this section a reference map would have been of great assistance.

The rocks described are nearly all Andesites and Dacites, and the work is mainly of value as giving a detailed study of these two groups, which are represented by very varied series, and a discussion of their relations. The author agrees with Rosenbusch in regarding the Dacites as entitled to rank as a distinct group, equivalent to that of the Andesites, and not as merely a type of the Amphibole or Mica Andesites. The Colombian volcanoes have yielded a very complete series of representatives of the two groups, as the silica percentage ranges from 54 per cent. to 78 per cent., so that all stages from felspar basalts to quartz trachytes are represented. Dr. Küch objects to Gümbel's classification into the two groups of the basaltic and trachytic types, and to Rosenbusch's classification of the dacites into the holocrystalline, felso-dacite, andesitic- and hyalo-dacite. The arrangement which he proposes divides both andesites and dacites into three groups; in the former the divisions are pyroxene-andesite, amphibole-pyroxene-andesite, and amphibole-andesite; in the latter are the "biotite-amphibole-dacite, pyroxene-amphibole-dacite, and pyroxene-dacite. These divisions may be useful for the purposes of a petrographical description of cabinet specimens, but they do not seem to be of value in the field, as the author points out that a transition may be traced from an augite-andesite to an amphibole-andesite in a single hand specimen; he thus objects to the view of Lagorio and Gümbel that these two types are sharply separated from one another.

The pyroxene-andesite is the most important of the andesites and a detailed description is given of the rock and its mineral constituents; among these, olivine and quartz are both present as accessories. Pyroxene is usually represented both by monoclinic and rhombic species, usually augite and hypersthene. The plagioclase ranges from andesine to bytownite, as is shown by the specific gravity of isolated crystals, a method which the author has applied somewhat extensively.

The amphibole-pyroxene-andesite is intermediate between the other two types; in it a crystal of augite is often enclosed in one of amphibole and *vice versa*: in the pyroxene andesite the amphibole never encloses the pyroxene; the author thus concludes that in the

latter the amphibole consolidated first, whereas in the amphibole-pyroxene-andesite the amphibole and pyroxene crystallized more or less simultaneously.

Amphibole-andesite is rare.

Among the Dacites the biotite-amphibole species is the most important. In this the felspar ranges between andesine and sanidine, and is often altered to opal. The most interesting part of the detailed description of this type is the discussion of the origin and significance of the so-called "corrosion-figures": he does not deny that crystals are sometimes corroded by the still fluid magma, but attributes many cases that would generally be attributed to this, to other influences, such as original deformations, oscillation, twins, mechanical strains, etc. A spherulitic structure, though of a somewhat imperfect type, occurs in this rock and in the pyroxene andesite. In the pyroxene-amphibole andesites, andesine is the chief plagioclase, while basaltic olivine is present as an accessory. Pyroxene-dacite was only once met with.

The last section of the "General Part" is devoted to the segregations, agglomerate-lavas, and ejected blocks and ashes. A felspar basalt is represented by specimens from three localities. A chapter is also devoted to the evidence afforded by 17 analyses, as to the chemical relations of andesite and dacite; the silicate percentage of the former ranges from 54·21 to 62·26 per cent.; and that of the latter from 63·36 to 70·22 per cent.

The "Special Part" dealing with the geographical distribution of rocks, occupies from pp. 89–192; the most interesting point brought out in this is the great variation of the rocks at each volcanic centre: thus andesites and dacites are associated, and usually in more than one variety of each.

The description of rock-specimens considered apart from their field relations is never of course the ideal method of petrography, as no doubt Dr. Küch would be quite ready to admit; but in the case of such distant and comparatively inaccessible areas as the Republic of Colombia, it is all that can be hoped for at present. The detailed descriptions of the rocks, however, will greatly lighten the labours of the lucky geologist to whose lot it may fall to work out their relations in the field. We must accordingly be grateful to Dr. Küch for the care with which he has investigated the materials, and to the two illustrious travellers whose careful collecting has added so greatly to our knowledge of the geology of the northern Andes. J. W. G.

III.—The Muir Glacier.

"Studies of the Muir Glacier, Alaska. By Harry Fielding Reid. National Geographic Magazine, Vol. IV., pp. 19–84, pls. i.–xvi. Washington, D. C., 1892.

THE exploration of Alaska is being rapidly advanced by the energy of the American geographers and geologists. The latest addition is a detailed study of the Muir Glacier, made last year by Professor Reid, and which has resulted in the correction of some very important errors in our previous knowledge of the

district. The principal measurements of the glacier as given by Professor Reid's survey are a length of 35 miles, a width varying from 6 to 10 miles and an area of 350 square miles. The thickness is 900 feet at the seaward end, and is much less than had been stated. The glacier slopes upward at 1° 15′ towards the nevé fields; the mountains around the glacier are from 5,000 to 7,000 ft. in height. The glacier is now receding very rapidly, and has retreated 1,000 yards in four years, a rate which far surpasses that ever attained by the Rosenlaui Glacier; its greatest extent was reached about 150–200 years ago. Around the fiord there is plenty of evidence of submerged forests, and Professor Reid therefore suggests that the diminution in the ice has been due to subsidence. The ablation is at the rate of 2 ins. a day, a measurement of much interest as reliable estimates for the Alaskan glaciers have been so far wanting. One of the most important parts of Professor Reid's work was his measurement of the rate of motion; this was calculated by Professor Wright at 70 ft. a day. Professor Reid's careful observations, however, show that this was enormously exaggerated, and that the very highest speed is 7 ft. 2 ins. a day. In a line across the glacier, a little above its mouth, the average daily motion was as follows: 4 ins., 2½ ft., 5¾ ft., 6½ ft., 4 ft. 8 ins., 6 ft. 1 in., 7 ft. 1 in., 7 ft. 2 ins., 6 ft. 2 ins., 4 ft. 9 ins., and 7 ins. The estimate of the amount of erosion that the glacier effects on its rock bed is also of interest. Professor Reid estimates that it amounts to as much as three-quarters of an inch per annum. The paper is illustrated by a series of photographs, which, though many of them are greatly over exposed, admirably depict the principal features of the greatest of the glaciers on the American mainland. J. W. G.

CORRESPONDENCE.

SHAPES OF SAND GRAINS. FLEXIBLE SANDSTONE.

Sir,—Mr. T. Mellard Reade in his interesting article on "Glacial Geology," in the July Number of the Geological Magazine refers —page 314—to the evidence afforded by the shapes of sand-grains in enabling us to determine the marine or fresh-water character of the deposit of which they form a part. As I have devoted many years to the study of Sands, perhaps I may be permitted to make a few remarks upon the subject.

Like Mr. Mellard Reade, I have examined Sands from many parts of the world, and I can endorse his views respecting the (generally) more-rounded appearance of marine sands than river-borne sands. I have found, however, that nearly all river-borne sands have a large percentage of *cylindrical* and *tabular* grains, while in wave-borne sands (remote from rivers) the percentage of such grains is very small. I have frequently explained what I believe to be the cause of this, and thence the value of the fact in enabling one to distinguish between those sands deposited by rivers, and those deposited by waves.

Mr. Mellard Reade states that "Blown-sand of sand-dunes is no distinguishably more worn than the sand of the shore from which i is derived." I do not know what particular dunes are referred to but I must say that my experience is quite the reverse of this Blown-sands of deserts and dunes procured from many parts of the world have never yet failed to provide me with characteristically-rounded grains in great abundance.

Of course much will depend on the particular spot from whence samples are procured. Grains freshly blown up from the shore on to the surfaces of dunes would not become appreciably rounded until they had travelled some distance inland, and had been whirled about in hollows and depressions for some length of time. The places to find rounded grains of blown-sand would be, therefore, in such depressions some distance from the shore, and I feel sure that anyone collecting samples from such spots will confirm my opinion. It must be clear that the action of the wind *in time*, by hurling the grains one against the other, would produce (in the case of quartz) sphericity through abrasion, and numerous sands prove this.

A fact that does not appear to be known in connection with grains of blown-sands is that many of the grains exhibit the *mastoid* markings so frequently seen on flint pebbles, and these markings clearly show with what force the grains have collided. I have never found these markings on wave-borne sand grains, simply because in the denser medium—water—the grains do not collide with sufficient force to enable them to become developed. Some years ago, at St. Agnes, in Cornwall, I found a deposit of white quartzose sand (probably Pliocene), the larger grains of which were covered with these markings, and these alone, I considered, pointed to the Eolian character of the deposit.

Before we can base any conclusion—as to the *locating agent* of a particular deposit—upon the rotundity of certain sand-grains contained therein, we must satisfy ourselves that such grains were not already rounded and polished in the parent rock from which they were derived.

In reference to Mr. Pittman's letter on "Flexible Sandstone," it does not appear to have been noticed that nearly thirty years ago Dr. Wetherell published an opinion that the flexibility was due to the grains being "arranged in definite groups separated from one another by intervening cavities." CECIL CARUS-WILSON.

BOURNEMOUTH, *July* 11, 1892.

SUBTERRANEAN EROSION OF THE GLACIAL DRIFT, A PROBABLE CAUSE OF SUBMERGED PEAT AND FOREST-BEDS.

SIR,—In December last a paper under this title was read before the Geological Society by Mr. William Shone, F.G.S., and more recently a *resumé* of it was given to the Chester Natural Science Society. The author described a section at Upton, near Chester, cut by two streamlets through Boulder-clay resting on a considerable thickness of sand. The clay sloped towards the sides of the streams,

and Mr. Shone stated that the percolation of water along the sand, towards the streamlets, had caused a subsidence of the clay to the amount of thirty feet. Not having seen the section I can give no definite opinion upon it, but in the paper referred to Mr. Shone endeavours to explain the subsidence of the Peat and Forest-beds at Ince, on the south shore of the Mersey, and on the west coast of England, as having been caused by the subterranean erosion or denudation of the underlying beds.

Mr. Shone gives the section of the Peat and Forest-beds from Ellesmere Port to Ince Ferry from my recently published "Geology of the Country around Liverpool," and assumes that the four basin-like depressions along the Manchester Ship Canal were caused by subterranean erosion and not by the deposition of silt and the growth of peat between ridges of sandstone. I do not, however, see that this theory can be satisfactorily applied to the post-Glacial beds referred to, for all the conditions are very different to those at Upton. It does not seem to be a logical conclusion to assume that because subterranean erosion occurs at Upton in consequence of a bed of sand underlying the Boulder-clay that it also occurs at Ince, in consequence of beds of grey silt and stiff clay underlying the Peat and Forest-beds. Mr. Shone refers to a bed of sand between the Boulder-clay and the post-Glacial beds at Ince; but it is quite a local deposit and changes to a grey clay within about 100 yards, and there is no such sand at Stanlow and Ellesmere, where the same amount of subsidence is shown. It does not seem possible that the beds of stiff clay could have been eroded beneath the surface under an area of several square miles of country, not only about Ince, but in other similar areas near Liverpool.

Mr. Shone's theory is, however, not original in connection with the district, for in 1854 the late Mr. John Cunningham, F.G.S., brought it before the British Association, and, so recently as 1887, in a paper read before the Liverpool Geological Society, and published in the Proceedings, on the "Stanlow, Ince, and Frodsham Marshes," I attributed the sinking of the land for about fifty yards along the edge of the Marshes to the influence of water from the river on a bed of sand underlying the grey clay and Peat and Forest-beds, but I afterwards found that the sand was not persistent, and that the slope of the land towards the Mersey was probably the original form of the ground. According to Mr. Shone's theory the surface of the land should fall rapidly along the edge of the Gowy and other streams, but I have seen no such subsidence.

Several instances have been described where the Peat and Forest-beds occurred on the Bunter Sandstone, many feet below the range of the tides. About Ince these beds rest on the rock in many places, and at various elevations. Along the shore on the north of the line of section the Peat and Forest-bed, with the trunks of trees, was seen resting on the Boulder-clay, and at the distance of a few yards on the rock.

The Boulder-clay rests on sand in cliff sections in many places around Liverpool, but I have never seen such an instance of subsidence caused by subterranean erosion as that described by

Mr. Shone. Possibly I may have overlooked some similar section, bu I do not remember reading of any such subsidence in older forma tions. It is very remarkable that such an active agent has not bee observed in the Tertiary formations of the South of England, whe the beds of clay and sand are similar, and occur under the sam conditions.

G. H. MORTON.

209, EDGE LANE, LIVERPOOL.
July 16th, 1892.

"CONE-IN-CONE" STRUCTURE.

SIR,—Observing that the "Cone-in-Cone" controversy still goe on in the GEOLOGICAL MAGAZINE, I beg you will permit me t remark in this connection, that the question whether this puzzlin formation occurs on both sides of slabs and nodular masses of cal careous rocks, clay-ironstone, etc., *i.e.* whether the apices of th layers of cones point upwards as well as downwards or not, was se at rest long since, at all events to *my* entire satisfaction [See GEOL MAG. for January, 1887, p. 17]. It seems to me that Fig. 5 therein entirely upsets Mr. Jno. Young's theory of how this rock was formed

Since I resided in U.S.A. my attention has repeatedly been called to double cone-in-cone (one layer over another, with the cones set in opposite directions) occurring in a certain bed of limestone in the Lower Productive Coal-measures of Western Pennsylvania, as well as in the Portage-beds of the Devonian series, upon which the place I write from is built; but as yet I have not had an opportunity of demonstrating that the said *double cone-in-cone* exists, by making a photograph of same *in situ*, which I mean to do as soon as possible, and send you a copy of. I may, however, say here, that this variety of cone-rock occurs both in flat irregular-shaped nodules or cakes, and also in beds, whenever or generally when the limestone-bed it runs in thins down to only a few inches. I do not imagine that the cone-in-cone *coal*, spoken of by Mr. Garwood in this month's GEOL MAG. (July, 1892, p. 334) can be of similar origin to that so often seen in clay-ironstones, limestones, etc. I think Mr. Garwood's cone-formation in coal is what miners sometimes call "cockscomb coal;" a structure commonly met with in the smokeless coal-beds of Glamorganshire, and more rarely in anthracite in Pembrokeshire. The "Hard mine" seam of N. Staffordshire sometimes exhibits a somewhat similar fracture, and I once detected cone-coal in the ordinary pit-coal (bituminous) of the "main" seam in Leicestershire. It runs in the semi-bituminous coals of Liege, Belgium. I look at it in coal as a kind of crystallization.

ERIE, PENNA., U.S.A.,
14*th July*, 1892.

W. S. GRESLEY, F.G.S.

MISCELLANEOUS.

WE have much pleasure in announcing that the Queen has been pleased to approve of the following promotion in the Most Honourable Order of the Bath (Civil Division); to be K.C.B., PROFESSOR WILLIAM HENRY FLOWER, C.B., F.R.S., Director of the British Museum (Natural History), Cromwell Road, S.W.